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IMPLEMENTING THE VISION FOR SPACE EXPLORATION: DEVELOPMENT OF THE CREW EXPLORATION VEHICLE

HEARING

BEFORE THE

COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED NINTH CONGRESS

SECOND SESSION

SEPTEMBER 28, 2006

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IMPLEMENTING THE VISION FOR SPACE EXPLORATION: DEVELOPMENT OF THE CREW EXPLORATION VEHICLE

THURSDAY, SEPTEMBER 28, 2006

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE,
Washington, DC.

The Committee met, pursuant to call, at 2:06 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Sherwood L. Boehlert [Chairman of the Committee] presiding.

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

Hearing on

Implementing the Vision for Space Exploration: Development of the Crew Exploration Vehicle

September 28, 2006
2:00 p.m. – 4:00 p.m.
2318 Rayburn House Office Building

WITNESS LIST

Dr. Scott Horowitz
Associate Administrator
Exploration Systems Mission Directorate
National Aeronautics and Space Administration

Mr. Allen Li
Director
Acquisition and Sourcing Management
Government Accountability Office

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HEARING CHARTER

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Implementing the Vision for Space Exploration: Development of the Crew Exploration Vehicle

THURSDAY, SEPTEMBER 28, 2006
2:00 P.M.–4:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Thursday, September 28th at 2:00 p.m. the House Committee on Science will hold a hearing to review the National Aeronautics and Space Administration's efforts to develop the Crew Exploration Vehicle (CEV), which NASA has recently announced will be called Orion. As laid out in the President's *Vision for Space Exploration,* Orion will carry humans to the International Space Station (ISS), the Moon, and beyond following the retirement of the Space Shuttle in 2010. On August 31st, 2006, NASA selected Lockheed Martin as its industry partner for the development and production of Orion, signing a development and production contract worth, including all options, approximately $8.1 billion through 2019.

On Wednesday the 26th of July, the Government Accountability Office (GAO) released a report critical of NASA's contracting approach for the acquisition of Orion. The report, entitled *"NASA: Long-Term Commitment to and Investment in Space Exploration Program Requires More Knowledge,"* faults the Agency for committing to a long-term contract for Orion before reaching an appropriate level of understanding of the design and risks of the program. The GAO report says, "NASA's current acquisition strategy for the CEV places the project at risk of significant cost overruns, schedule delays and performance shortfalls because it commits the government to a long-term product development effort before establishing a sound business case."

Following discussions with the GAO and the Science Committee, NASA revised its then pending contract with Lockheed Martin to address some of the GAO's concerns.

NASA and Lockheed Martin have now started work under the Orion contract and expect to complete development by 2014 with a first demonstration flight occurring in 2013. Overall, NASA will be depending in part on the skills and knowledge in the contractor community to reach a final design for Orion. GAO argues that this design activity should be separated from longer-term production, allowing the government to have greater leverage to seek beneficial production terms. NASA, however, has chosen to include the entire design and production of Orion into one contract with the hopes that this will help control total life cycle costs. This hearing will explore NASA's development schedule and costs and provide a basis for ongoing oversight of this program.

Witnesses

Dr. Scott J. (Doc) Horowitz, Associate Administrator, Exploration Systems Mission Directorate, NASA

Mr. Allen Li, Director, Acquisition and Sourcing Management, Government Accountability Office

Overarching Questions

1) What is NASA's strategy for developing Orion?
2) Does NASA have the knowledge required to enter into a long-term development contract?
3) What steps can NASA take to ensure timely and cost-effective development of Orion?

Background

Following President Bush's January 14th, 2004 announcement of the *Vision for Space Exploration,* NASA began a number of studies to determine how the Agency could implement the new direction laid out in the President's speech. The agency announced the results of its *Exploration Systems Architecture Study* (ESAS) in September, 2005 and has continued to refine this approach to date.

NASA has presented a plan designed to enable a crew of four to land anywhere on the Moon, stay for up to seven days initially, and abort and return to Earth at anytime. To enable this mission concept, NASA has chosen to separate crew and cargo using two new launch vehicles. Crew will travel aboard the Crew Exploration Vehicle, now called Orion, a capsule capable of supporting a crew of four to six. Orion will initially transport crew to the International Space Station and will eventually ferry astronauts to the Moon and back. This design will include a launch escape system that should allow the crew to safely abort in the event of a launch failure. NASA argues that this design has a safety factor many times higher than that of the current Space Shuttle. The capsule will launch on top of a new launch vehicle, previously described as the Crew Launch Vehicle (CLV), and which has recently been named the Ares I. This launch vehicle will use the Space Shuttle's Solid Rocket Booster (SRB) as an initial stage and an upper stage utilizing an Apollo derived engine, the J–2X. After Orion and Ares I have been developed, NASA plans to begin work on a new heavy-lift launch vehicle of a capacity slightly greater than that of the Saturn V. This vehicle, the Ares V, would launch the equipment needed to land on the Moon—equipment the CEV would link up with in low-Earth orbit. Ares V will utilize two Space Shuttle SRBs and five engines from the Boeing Delta IV, on an external tank similar to Shuttle's. NASA is calling the overall program for the development of Orion, Ares I and V, and future lunar activities the Constellation Systems program.

Issues

What has NASA committed to in the Orion development contract with Lockheed Martin?

Lockheed Martin was selected for the Orion contract on August 31, winning out over a partnership between Northrup Grumman and Boeing. The Lockheed contract is expected to cost about $3.9 billion for development and testing of two test flight capsules; it is a cost-plus contract so the exact figure cannot yet be known. The signed contract also includes two additional options, named Schedules B and C, under which NASA would contract with Lockheed to produce the operational vehicles. Schedules B and C include price ceilings for the vehicles and associated support services. The contract value of the options totals approximately $4.25 billion through 2019 assuming a schedule of five flights per year.

Initially, the contract did not make clear that Schedules B and C were options and that therefore the government could end the contract prior to production of operational vehicles without penalty. As a result of the GAO study, the contract language was changed so that it is now clear that Schedules B and C are options.

Why was Lockheed Martin chosen?

Selection documents show that NASA judged Lockheed Martin's bid superior based on cost, technical approach, and past performance.

Does NASA have the knowledge needed to sign a long-term contract?

GAO's first concern is the Agency's approach of committing to a long-term contract for Orion before completing design work and developing a firmer cost estimate. GAO fears that committing now to a long-term development contract could raise costs as design changes are worked out.

Responding to the GAO report, NASA argues that it has a good sense of how the project will proceed because it is largely based on existing technology developed for the Apollo or Shuttle programs. Also, NASA points out that two teams of NASA employees conducted design studies independent of the contractor (and of the NASA teams was independent of the Constellation program). NASA also believes that making clear that Schedules B and C are merely options has also reduced the risk of cost overruns.

NASA also has included explicit milestones for the contractor to meet and given the government the ability to terminate the contract if the project is not meeting NASA's requirements.

GAO, in turn, points out that space projects in general, and NASA's in particular do not have a good record of coming in within expected costs. GAO also points out that NASA still does not have a final design or cost estimate for Orion or Ares I.

NASA has just begun the detailed design work necessary before production of the first test units. NASA expects to have preliminary designs completed by summer 2008 and final designs by spring 2010.

Why has NASA chosen a long-term contract?

NASA says it requires industry expertise to complete the design and development of Orion. While NASA is engaging all of its centers in the development projects within Constellation, the Agency says it does not have sufficient personnel in critical areas to complete the designs in-house.

GAO recommended that NASA could mitigate its contract risk without delaying the project by moving forward with a contract to carry the program only through its design phase to the Preliminary Design Review (PDR) milestone, scheduled for summer 2008. During the PDR, NASA will verify that the designs for Orion meet all of the requirements for the system. At PDR, NASA (and industry) will have a much better understanding of the program and be in a stronger position to make firm commitments to cost and schedule for the development. NASA, however, has chosen to include the entire design and development of Orion into one contract with the expectation that this will help control total life cycle costs because, among other reasons, it removes the incentive to push off expenses to later stages of the contract.

What are the technical challenges that face the Constellation Program?

NASA believes that there are no areas in the Orion concept where the technology is immature and poses significant development risks. When pressed, NASA officials have said the hardest aspect of the project will be “systems integration”—enabling elements that were originally designed for other vehicles to work together. In addition, NASA has begun focused efforts on technology areas that are currently perceived to hold the most risk, including efforts to address early risks in the thermal protection and landing systems. However, given the early stage of development of the project, the risks for the overall program are not clear. For the next year, NASA and Lockheed Martin will work to complete a set of well-defined requirements, a preliminary design, and firm cost estimates.

What is the likelihood of further technical changes to Orion?

As GAO notes in its report, NASA has made a number of significant changes to the Exploration Systems architecture since its announcement in September 2005. These include decreasing the diameter of Orion from 5.5 meters to five meters, moving from use of the Space Shuttle Main Engine (SSME) to an Apollo-derived engine, the J–2X, on the Ares I, and moving to the Delta IV engine on the Ares V. Further changes are expected, particularly as engine testing determines exactly how much weight the engines are capable of lifting.

What is the development timeframe for Orion and Ares I?

The *NASA Authorization Act of 2005* directs NASA to launch Orion as close to 2010 as possible to minimize the time between the last Shuttle launch and the first launch of Orion. NASA had hoped to have Orion launch by 2012—two years earlier than initially planned—but has not concluded that it will not have the funding to accomplish that.

Orion and Ares I are currently in the early stages of development. Significant design and development activities remain for both projects, including finalizing top-level requirements and drafting detailed engineering designs. This fall, both vehicles will begin System Requirement Reviews that will finalize the basic parameters of the system. Preliminary design work will be reviewed during the summer of 2008, with final reviews before commencing production occurring during the spring of 2010. NASA expects to complete a preliminary test of the first stage of Ares I in late 2009. Operational tests of the full system will not occur until fall of 2013.

Orion / Ares I	
System Requirements Review The SRR examines the functional and performance requirements defined for the system and the preliminary program or project plan and ensures that the requirements and the selected concept will satisfy the mission. SRR is typically conducted during the concept development phase following completion of the concept studies phase.	Fall 2006
Preliminary Design Review The Preliminary Design Review (PDR) demonstrates that the preliminary design meets all system requirements with acceptable risk and within the cost and schedule constraints and establishes the basis for proceeding with detailed design. It will show that the correct design option has been selected, interfaces have been identified, and verification methods have been described.	Summer 2008
Critical Design Review The purpose of the CDR is to demonstrate that the maturity of the design is appropriate to support proceeding with full scale fabrication, assembly, integration, and test, and that the technical effort is on track to complete the flight and ground system development and mission operations in order to meet mission performance requirements within the identified cost and schedule constraints. CDR occurs near the completion of the final design phase and always before entering the fabrication, assembly, and test phase.	Spring 2010
Demonstration Flights	Fall 2013

What are the projected costs for Constellation development?

Due to the uncertainty inherent in estimating costs for development of new products, NASA develops a cost range based on past performance and cost models. Traditionally NASA has budgeted for new developments at a confidence of 50 percent, meaning that the project stood an equal chance of having an actual cost above or below the estimate. A higher confidence levels reflects a greater chance of the actual cost of a project coming in under the estimate. There is an ongoing debate within the space community about the appropriate confidence level for space acquisitions, with many critics suggesting the need for higher confidence levels. The Air Force has recently switched to a policy of requiring estimates at the 80 percent level.

NASA predicts the Orion development effort will cost $18.3 billion from 2006 to 2020 at 65 percent confidence including both contractor and government costs. In the near-term, NASA predicts that the cost of the Constellation program through 2011, when NASA would begin testing Orion and Ares I, is $32.1 billion with 80 percent confidence. Finally, NASA believes that the cost of returning to the Moon by 2018 may be around $104 billion, but NASA has not yet performed a detailed analysis of this cost. GAO estimates the total Constellation costs through 2018 total $122 billion. For Constellation, most of the development risk lies beyond the 2012 timeframe, when NASA begins work on the various craft needed to support a lunar mission.

GAO notes that the FY 2007 budget does not fully support the costs laid out in the original *Exploration Systems Architecture Study* (ESAS), completed last summer. GAO estimates that NASA does not have sufficient funding budgeted to support the architecture during FY 2008, 2009, and 2010. However, NASA's approach to implementing the exploration architecture has evolved significantly since the ESAS report making it difficult to determine what shortfall may occur. NASA has continued to refine its cost estimates internally, but has embargoed that information pending the release of the FY 2008 budget.

What implications would cost growth in Constellation have for other programs at NASA?

As noted by GAO, it is unclear if NASA has the budget to support the Vision as laid out in ESAS. NASA has announced its intention to carry over funds in the Exploration Systems Mission Directorate from fiscal years 2006, 2007, and 2008 to cover the expected large costs in 2009 and 2010. NASA expects to shift resources away from the Shuttle program after its retirement to Constellation. Despite these resources, the Agency remains challenged to support development of Orion by 2014. NASA has stated that it will pursue a lunar return program under a philosophy of "go-as-you-can-afford-to-pay." Specifically:

> NASA's plan is to contain [CEV] costs within the human space flight budget, thereby, impacting the content of other projects and programs within that budget. Thus, a higher than expected CEV cost would simply delay CEV development or production or impact other programs and projects within that human space flight budget category. NASA continues its 'go-as-you-can-afford-to-pay' strategy toward all of our missions of space exploration, scientific discovery, and aeronautics research.

The Authorization Act requires NASA to balance its human space flight, space science, Earth science, and aeronautics programs.

Witness Questions

The witnesses were asked to address the following questions in their testimony:

Dr. Scott Horowitz

1. What is NASA's strategy for reducing the total cost for production and operation of the CEV?
2. What actions has NASA taken to address the concerns raised in the GAO report entitled "NASA: Long-Term Commitment to and Investment in Space Exploration Program Requires More Knowledge"?

Mr. Allen Li

1. To what degree does NASA's approach deviate from "best practices" for large system acquisitions?
2. NASA has claimed that implementing the GAO's recommendations would delay the delivery of the CEV and increase costs. Please explain why you agree or disagree with NASA's claim.
3. Does NASA have the financial resources necessary to complete the adopted acquisition strategy? What particular areas have the potential for significant cost growth?
4. What indicators would the GAO identify in order to gauge the progress of CEV development?

Appendix A

Excerpts of NASA Authorization Act of 2005 on CEV

TITLE I—GENERAL PRINCIPLES AND REPORTS

SEC. 101. RESPONSIBILITIES, POLICIES, AND PLANS.

(b) Vision for Space Exploration—

(1) IN GENERAL—The Administrator shall establish a program to develop a sustained human presence on the Moon, including a robust precursor program, to promote exploration, science, commerce, and United States preeminence in space, and as a stepping-stone to future exploration of Mars and other destinations. The Administrator is further authorized to develop and conduct appropriate international collaborations in pursuit of these goals.

(2) MILESTONES—The Administrator shall manage human space flight programs to strive to achieve the following milestones (in conformity with section 503)—

(A) Returning Americans to the Moon no later than 2020.

(B) Launching the Crew Exploration Vehicle as close to 2010 as possible.

(C) Increasing knowledge of the impacts of long duration stays in space on the human body using the most appropriate facilities available, including the ISS.

(D) Enabling humans to land on and return from Mars and other destinations on a timetable that is technically and fiscally possible.

SEC. 102. REPORTS.

(b) Budget Information—Not later than April 30, 2006, the Administrator shall transmit to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a report describing—

(1) the expected cost of the Crew Exploration Vehicle through fiscal year 2020, based on the public specifications for that development contract; and

(2) the expected budgets for each fiscal year through 2020 for human space flight, aeronautics, space science, and Earth science—

(A) first assuming inflationary growth for the budget of NASA as a whole and including costs for the Crew Exploration Vehicle as projected under paragraph (1); and

(B) then assuming inflationary growth for the budget of NASA as a whole and including at least two cost estimates for the Crew Exploration Vehicle that are higher than those projected under paragraph (1), based on NASA's past experience with cost increases for similar programs, along with a description of the reasons for selecting the cost estimates used for the calculations under this subparagraph and the confidence level for each of the cost estimates used in this section.

SEC. 103. BASELINES AND COST CONTROLS.

(a) Conditions for Development—

(1) IN GENERAL—NASA shall not enter into a contract for the development of a major program unless the Administrator determines that—

(A) the technical, cost, and schedule risks of the program are clearly identified and the program has developed a plan to manage those risks;

(B) the technologies required for the program have been demonstrated in a relevant laboratory or test environment; and

(C) the program complies with all relevant policies, regulations, and directives of NASA.

(2) REPORT—The Administrator shall transmit a report describing the basis for the determination required under paragraph (1) to the Committee

on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate at least 30 days before entering into a contract for development under a major program.

(3) NONDELEGATION—The Administrator may not delegate the determination requirement under this subsection, except in cases in which the Administrator has a conflict of interest.

TITLE V—HUMAN SPACE FLIGHT

SEC. 501. SPACE SHUTTLE FOLLOW-ON.

(a) Policy Statement—It is the policy of the United States to possess the capability for human access to space on a continuous basis.

(b) Progress Report—Not later than 180 days after the date of enactment of this Act and annually thereafter, the Administrator shall transmit a report to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate describing the progress being made toward developing the Crew Exploration Vehicle and the Crew Launch Vehicle and the estimated time before they will demonstrate crewed, orbital space flight.

(c) Compliance Report—If, one year before the final planned flight of the Space Shuttle orbiter, the United States has not demonstrated a replacement human space flight system, and the United States cannot uphold the policy described in subsection (a), the Administrator shall transmit a report to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate describing—

(1) strategic risks to the United States associated with the failure to uphold the policy described in subsection (a);

(2) the estimated length of time during which the United States will not have its own human access to space;

(3) what steps will be taken to shorten that length of time; and

(4) what other means will be used to allow human access to space during that time.

SEC. 502. TRANSITION.

(a) In General—The Administrator shall, to the fullest extent possible consistent with a successful development program, use the personnel, capabilities, assets, and infrastructure of the Space Shuttle program in developing the Crew Exploration Vehicle, Crew Launch Vehicle, and a heavy-lift launch vehicle.

(b) Plan—Not later than 180 days after the date of enactment of this Act, the Administrator shall transmit to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a plan describing how NASA will proceed with its human space flight programs, which, at a minimum, shall describe—

(1) how NASA will deploy personnel from, and use the facilities of, the Space Shuttle program to ensure that the Space Shuttle operates as safely as possible through its final flight and to ensure that personnel and facilities from the Space Shuttle program are used in NASA's exploration programs in accordance with subsection (a);

(2) the planned number of flights the Space Shuttle will make before its retirement;

(3) the means, other than the Space Shuttle and the Crew Exploration Vehicle, including commercial vehicles, that may be used to ferry crew and cargo to and from the ISS;

(4) the intended purpose of lunar missions and the architecture for those missions; and

(5) the extent to which the Crew Exploration Vehicle will allow for the escape of the crew in an emergency.

SEC. 504. GROUND-BASED ANALOG CAPABILITIES.

(a) Policy—It is the policy of the United States to achieve diverse and growing utilization of, and benefits from, the ISS.

(b) Elements, Capabilities, and Configuration Criteria—The Administrator shall ensure that the ISS will—

(1) be assembled and operated in a manner that fulfills international partner agreements, as long as the Administrator determines that the Shuttle can safely enable the United States to do so;

(2) be used for a diverse range of microgravity research, including fundamental, applied, and commercial research, consistent with section 305;

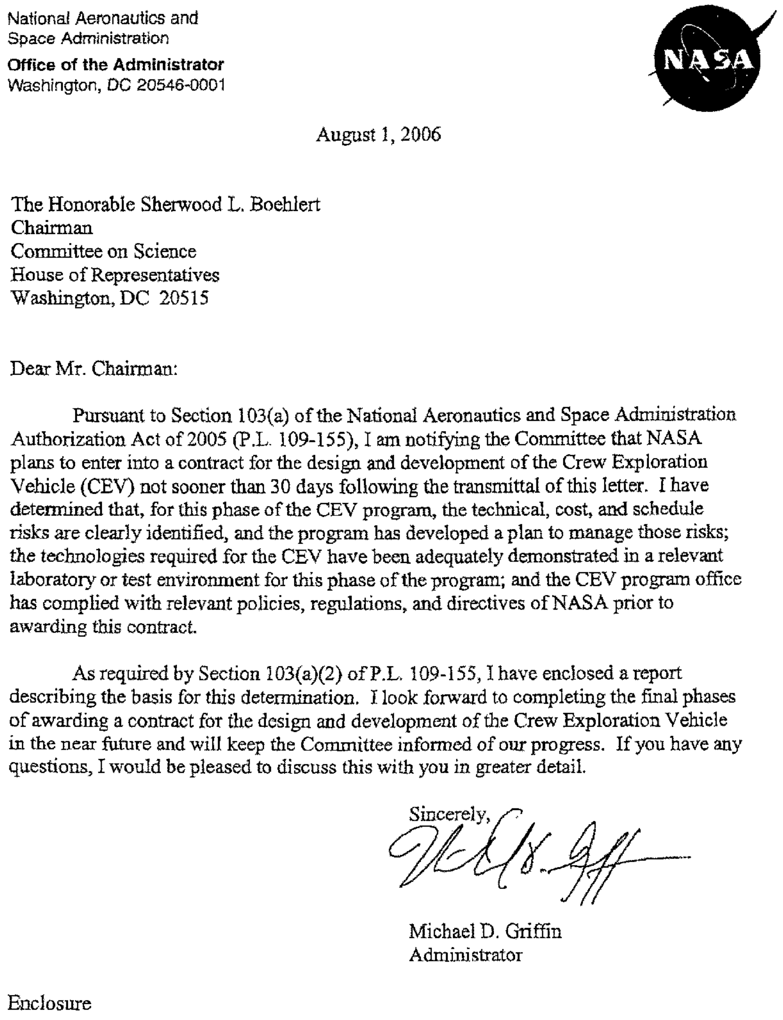
(3) have an ability to support a crew size of at least six persons, unless the Administrator transmits to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate not later than 60 days after the date of enactment of this Act, a report explaining why such a requirement should not be met, the impact of not meeting the requirement on the ISS research agenda and operations and international partner agreements, and what additional funding or other steps would be required to have an ability to support crew size of at least six persons;

(4) support Crew Exploration Vehicle docking and automated docking of cargo vehicles or modules launched by either heavy-lift or commercially-developed launch vehicles;

(5) support any diagnostic human research, on-orbit characterization of molecular crystal growth, cellular research, and other research that NASA believes is necessary to conduct, but for which NASA lacks the capacity to return the materials that need to be analyzed to Earth; and

(6) be operated at an appropriate risk level.

Appendix B:



National Aeronautics and
Space Administration
Office of the Administrator
Washington, DC 20546-0001

August 1, 2006

The Honorable Sherwood L. Boehlert
Chairman
Committee on Science
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Pursuant to Section 103(a) of the National Aeronautics and Space Administration Authorization Act of 2005 (P.L. 109-155), I am notifying the Committee that NASA plans to enter into a contract for the design and development of the Crew Exploration Vehicle (CEV) not sooner than 30 days following the transmittal of this letter. I have determined that, for this phase of the CEV program, the technical, cost, and schedule risks are clearly identified, and the program has developed a plan to manage those risks; the technologies required for the CEV have been adequately demonstrated in a relevant laboratory or test environment for this phase of the program; and the CEV program office has complied with relevant policies, regulations, and directives of NASA prior to awarding this contract.

As required by Section 103(a)(2) of P.L. 109-155, I have enclosed a report describing the basis for this determination. I look forward to completing the final phases of awarding a contract for the design and development of the Crew Exploration Vehicle in the near future and will keep the Committee informed of our progress. If you have any questions, I would be pleased to discuss this with you in greater detail.

Sincerely,

Michael D. Griffin
Administrator

Enclosure

NASA Report on Cost Estimates for the Crew Exploration Vehicle (CEV) and Other Agency Program Budgets through 2020

JUNE 2006

This report responds to the requirements of Section 102 of the *NASA Authorization Act of 2005* (P.L. 109–155) to provide cost and budget information for the Crew Exploration Vehicle (CEV), as well as other Agency programs through 2020.

The current estimate of total nonrecurring cost for the Crew Exploration Vehicle from fiscal year 2006 through 2020 is $18.3 billion. There are many assumptions behind this estimate, which require a fill explanation. First, this assumes that the first CEV test flights would begin no later than 2012, and the first operational demonstration flight of the CEV to the International Space Station (ISS) would be no later than 2014. This estimated total cost includes design, development, test, and evaluation (DDT&E) and production costs for the CEV through 2020; but does not include the recurring cost of operations. This total nonrecurring cost includes not only expected contract costs, but also all Government costs associated with the CEV. This preliminary estimate is based on the exploration architecture NASA developed during last year's Exploration System Architecture Study and forms the basis for NASA's FY 2007 budget. Given that the requirements and acquisition processes are still under way, NASA performed cost risk analyses to develop the cost estimate with a 65 percent cost confidence level to arrive at the total budget. This confidence level is appropriate for this phase of the CEV project.

NASA considers the confidence level of 65 percent to be appropriate for two reasons. First, the CEV definition is not complete, and the distribution on CEV cost is still fairly wide, reflective of the uncertainty in definition. A wide cost distribution requires more cost reserve to achieve 65 percent confidence than will be the case once the CEV definition has matured and some cost risk has been retired, leading to a narrower cost distribution. Once NASA retires risk and the CEV cost distribution narrows, the Agency could find that the CEV cost estimate of $18.3 billion is greater than 65 percent confidence. But to be prudent at this point, NASA is carrying enough reserve to achieve a 65 percent confidence level even on the wide cost distribution that now exists on CEV. Secondly, carrying 65 percent confidence level cost estimates on individual projects such as CEV results in about an 80 percent cost confidence for the total Constellation Program. In investing, this is called the "portfolio effect." In the case of the Constellation portfolio, since the CEV Program is at the 65 percent confidence level on each individual project, the probability is that only a few of the individual projects will overrun. At 65 percent confidence, more projects will underrun than overrun, and the total reserve at the Constellation level should be more than sufficient.

The *NASA Authorization Act* also asks NASA to report at least two cost estimates for the CEV that are higher than those NASA had projected, but based on NASA's past experience. To arrive at two higher CEV cost estimates, NASA would add additional program cost reserves to its estimates for the work to be done. Thus, while our current estimate of total costs for the CEV is $18.3 billion at 65 percent confidence for fiscal years 2006–2020, NASA's cost estimates at higher confidence levels are $20.3 billion for 70 percent cost confidence and $23.8 billion for 80 percent cost confidence. The higher cost estimates provide additional reserve to address technical and schedule uncertainties. However, for the level of maturity in the designs and plans NASA has at this time, NASA firmly believes that a 65 percent confidence level is the appropriate level of confidence for our cost estimates at this early phase (Phase A) of the CEV project. NASA will also be employing a rigorous Continuous Cost-Risk Management (CCRM) approach to retire risks as we progress from Phase A through Phase B (Preliminary Design). By effectively managing our risks in this fashion, the cost confidence for the $18.3 billion estimate is expected to increase as NASA proceeds with Final Design and Fabrication (Phases C and D, respectively) of the CEV.

The *NASA Authorization Act* further asks NASA for the expected budgets for each fiscal year through 2020 for human space flight, aeronautics, space science, and Earth science. NASA's five-year budget run-out assumptions for fiscal years 2006–2011 are presented as part of NASA's FY 2007 budget request. The budget figures for the years after 2011 must be considered notional at best.

See the enclosed charts for this information, which requires further explanation. The Act asks NASA to assume inflationary growth for its' top-line budget, so in the attached charts we show notional growth at this level for NASA's programs, based on the 2011 budget. NASA assumes an inflationary growth rate of 2.4 percent per year. For the purpose of this report, the human space flight budget is treated as NASA's budget categories of Space Operations, except for the Space and Flight Support theme and Exploration Systems. The Act then asks NASA to assume the higher cost estimates for the CEV provided above in its report of expected budgets for each fiscal year. However, we should not confuse costs with budget in this analysis. These are our cost estimates for the CEV with different confidence levels to that expected cost. If there is a change in the cost estimates, NASA will not necessarily change the budget plans. Instead, NASA's plan is to contain those costs within the human space flight budget, thereby, impacting the content of other projects and programs within that budget. Thus, a higher than expected CEV cost would simply delay CEV development or production or impact other programs and projects within that human space flight budget category. NASA continues its "go-as-you-can-afford-to-pay" strategy toward all of our missions of space exploration, scientific discovery, and aeronautics research.

NASA: FY 2007 President's Budget

(Budget Authority in Millions)	FY 2006 Op Plan	FY 2007	Change	FY 2008	FY 2009	FY 2010	FY 2011
SCIENCE, AERO & EXPLOR.	9,721.3	10,524.4	8.3%	10,594.4	11,136.4	11,747.0	15,526.4
SCIENCE	5,253.7	5,330.0		5,383.1	5,437.1	5,491.5	5,546.4
Solar System Exploration	1,582.3	1,610.2		1,598.6	1,840.4	1,899.6	1,846.7
Universe	1,507.9	1,509.2		1,500.9	1,307.9	1,276.1	1,309.7
Earth-Sun System	2,163.5	2,210.6		2,283.7	2,288.9	2,315.8	2,390.0
EXPLORATION SYSTEMS	3,050.1	3,978.3		3,981.6	4,499.8	5,055.9	8,775.1
Constellation Systems	1,733.5	3,057.6		3,067.6	3,612.9	4,083.8	7,698.4
Exploration Sys Res & Tech	692.5	646.1		632.2	605.1	679.2	764.6
Human Sys Reseach & Tech	624.1	274.6		281.8	281.8	292.8	312.1
AERONAUTICS RESEARCH	884.1	724.4		731.8	732.4	722.8	722.7
CROSS-AGENCY SUPPORT PR	533.6	491.7		497.9	467.1	476.8	482.2
Education Programs	162.4	153.3		152.4	153.1	154.0	153.3
Advanced Business Systems	156.3	108.2		106.9	73.8	78.5	80.6
Innovative Partnerships	214.8	197.9		205.6	206.2	209.7	212.9
Shared Capabilities	0.0	32.2		33.1	33.9	34.7	35.5
EXPLORATION CAPABILITIES	6,869.7	6,234.4	-4.4%	6,680.4	6,442.3	6,242.9	2,896.7
SPACE OPERATIONS	6,869.7	6,234.4		6,680.4	6,442.3	6,242.9	2,896.7
International Space Station	1,753.4	1,811.3		2,200.3	2,255.6	2,197.1	2,360.8
Space Shuttle*	4,777.5	4,056.7		4,087.3	3,794.8	3,651.1	146.7
Space and Flight Support	338.8	366.5		392.8	392.0	394.7	389.2
INSPECTOR GENERAL	32.0	33.5	4.7%	34.6	35.5	36.4	37.3
TOTAL AGENCY	16,623.0	16,792.3	3.2%	17,309.4	17,614.2	18,026.3	18,460.4
*yr to yr increase***			3.2%	3.1%	1.8%	2.3%	2.4%

** Includes emergency supplemental of $349.8 million in FY 2006.*

*** Not including emergency supplemental of $349.8 in FY 2006*

The 2007 President's Budget: Authorization Act Categories

The 2007 Projections: Authorization Act Categories

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Human Spaceflight	$9,581	$9,846	$10,269	$10,550	$10,904	$11,283	$11,565	$11,854	$12,150	$12,454	$12,765	$13,084	$13,411	$13,747	$14,090
Space Science	$3,090	$3,119	$3,099	$3,148	$3,176	$3,156	$3,235	$3,316	$3,399	$3,484	$3,571	$3,660	$3,752	$3,846	$3,942
Earth Science	$2,163	$2,211	$2,284	$2,289	$2,316	$2,390	$2,450	$2,511	$2,574	$2,638	$2,704	$2,772	$2,841	$2,912	$2,985
Aeronautics	$884	$724	$732	$732	$723	$723	$741	$759	$778	$798	$818	$838	$859	$881	$903
Other	$904	$891	$925	$894	$908	$908	$931	$955	$979	$1,003	$1,028	$1,054	$1,080	$1,107	$1,135
Total NASA	$16,623	$16,792	$17,309	$17,614	$18,026	$18,460	$18,922	$19,395	$19,880	$20,377	$20,886	$21,408	$21,944	$22,492	$23,055

- **This projection assumes inflationary growth of 2.5% for NASA's top-line from 2012 to 2020**
  - **NASA's budget will evolve as we return the Shuttle to flight, more fully utilize the ISS, and return to the Moon.**
- **Human Space Flight**
  - **Constellation Systems Theme, ESRT, and HSRT Themes.**
  - **Space Shuttle Theme, International Space Station Theme.**
- **Space and Earth Science**
  - **Space Science -> The Universe Theme, Solar System Exploration Theme (the Astrophysics and Planetary Science Divisions of the Science Mission Directorate, respectively).**
  - **Earth Science -> Earth-Sun System Theme (includes both the Earth Science and Heliophysics Divisions of the Science Mission Directorate).**
- **Aeronautics**
  - **Aeronautics Research Mission Directorate.**
- **Other Includes: Space and Flight Support Theme of SOMD, Cross Agency Support Programs**
  - **These elements provide support to all of NASA's missions and, therefore, are not appropriately characterized as either Human Space Flight or Science.**

Appendix C:

Notification Concerning the Award of the Crew Exploration Vehicle Development Contract

Preface

The National Aeronautics and Space Administration intends to award a design, development, production, and support contract for the Crew Exploration Vehicle (CEV) not sooner than August 31, 2006. The following report has been prepared pursuant to direction in Section 103(a) of the *National Aeronautics and Space Administration Authorization Act of 2005* (P.L. 109–155) to support the Administrator's determination.

1.0 Introduction

The *Vision for Space Exploration* has specific goals and objectives of retiring the Shuttle by no later than 2010, providing CEV operational availability no later than 2014, and returning humans to the Moon by 2020. During the summer of 2005, NASA conducted the Exploration Systems Architecture Study (ESAS) to define the system architecture and concepts for the CEV. The architecture recommended by the ESAS defines the CEV as a crew module, service module, and launch abort system arrangement similar to that of Apollo. This architecture was determined to be the least costly, most rapid, and safest approach for bringing the lunar missions to fruition in a timely manner.

2.0 Business Case, Acquisition Strategy, and Status

NASA requires the development of a sound business case prior to committing the Government to a long-term product development effort. In establishing the acquisition strategy for the CEV, NASA utilized a knowledge-based and performance-based acquisition framework, as outlined in this report, which defines how the Agency implemented these provisions for the planned development, production, and fielding of this new human space vehicle. Additionally, NASA is maximizing competition by soliciting from industry their development, production, and management approach with an emphasis on Life Cycle Cost (LCC) for the CEV. The foundation of the CEV acquisition strategy is to seek commitment from industry for a design solution and to control LCC through competition and incentives. While in this competitive environment, NASA will receive firm competitive prices from industry to complete development of the CEV and demonstrate a crewed vehicle and an uncrewed cargo vehicle. Under this competition, NASA will also establish "not-to-exceed" prices for the production of the required vehicles to support the current flight manifest through 2019.

The CEV acquisition utilizes a phased approach. Lockheed Martin and Northrop Grumman were selected and awarded Phase 1 contracts in July of 2005. These two vendors will remain under contract until one is selected for Phase 2 of the acquisition. To minimize the Government's obligation during design and development, NASA's acquisition for Phase 2 divides the CEV contract into three different schedules:

- Schedule A, for design, development, test, and evaluation (DDT&E) and production of the first certified flight units of the crewed and uncrewed vehicle. Schedule A also includes the units necessary to perform the flight tests required to certify the CEV.
- Schedule B, for production of flight units beyond the first certified flight units produced in Schedule A.
- Schedule C, for sustaining activities during production and operation.

Schedule A is authorized at contract award and runs through the first flight demonstration of each design variant of the CEV. Schedule A aids the formulation phase of the project by allowing NASA to utilize the contractor's knowledge to develop a set of validated requirements including component specifications by the project's Preliminary Design Review (PDR). The CEV acquisition strategy will allow NASA and the contractor to jointly attain knowledge about the project and required resources that will enable the generation of firm cost, schedule, and risk elements. Shortly after PDR, the Non-Advocacy Review (NAR) will be held to establish the firm project baseline and provide assurances to our stakeholders that NASA has the necessary knowledge to move the project forward into development.

Schedule B is a contract option planned to be authorized post-PDR, NAR, and after the Critical Design Review (CDR). Schedule B will be used to produce all the flight units other than the first two units produced under Schedule A. Schedule C is an additional contract option and is planned to be authorized at approximately the same time as Schedule B. The CEV strategy does not commit the Agency to production until the NAR milestone is met. First production orders are planned for the fall of 2009, nine months after the official acceptance by NASA of the baseline of the CEV's design at CDR.

The acquisition strategy being utilized for CEV provides an effective knowledge- and performance-based approach for NASA. This strategy is designed to coincide with the GAO-defined Knowledge Points and minimizes the Government's obligation accordingly. Use of Delivery Orders provides NASA the ability to order only the units and sustaining engineering necessary, with appropriate incentives, at a time when the requirement and costs are better understood by NASA and industry. Inherent in this strategy is the ability for the Government to terminate these efforts if performance does not meet expectations.

3.0 CEV Policy, Regulation, and Directive Compliance

These acquisitions, as well as the project plan, have been built in compliance with all NASA's defined policies, regulations, and directives and, in particular, the following key documents:

- A Renewed Spirit of Discovery: The President's Vision for U.S. Space Exploration.
- The *National Aeronautics and Space Administration Authorization Act of 2005* (Public Law 109–155).
- NASA Policy Directive 7120AC—Program/Project Management.
- NASA Procedural Requirement 7120.5C—NASA Program and Project Management Processes and Requirements.
- NASA Procedural Requirement 7123.1—Systems Engineering Procedural Requirements.
- NASA Procedural Requirement 8000.4—Risk Management Procedural Requirements.
- NASA Policy Directive 8700.1 C—NASA Policy for Safety and Mission Success.
- 48 CFR 1800–1899—Federal Acquisition Regulation Supplement (NASA/FAR Supplement).

4.0 Technology Maturation

NASA has not identified any areas in the CEV concept where the technology is immature. To further improve and characterize NASA's knowledge, the Agency has in-house advanced development plans (ADP) to mitigate cost and schedule risk for those areas that are deemed to have the most risk for CEV development. The architecture design chosen by NASA, informed by the ESAS study, and requirements maturation through the Phase 1 trades and analysis, permits the use of mature technology and high-pedigree heritage hardware with space flight experience.

The Phase 2 proposals have been evaluated for technology risks. Specifically, the CEV Phase 1 contractors provided a priority list of all risks with a narrative of their mitigations, mitigation costs and schedules, and projected mitigation action result. In addition, the CEV Phase 1 contractors' narratives included fall-back options for technologies and their impact to cost and schedule, if used.

With these ADP efforts, Phase 2 proposals are being evaluated for technical risk and risk-reduction testing. NASA has confidence that the technologies have been effectively demonstrated to proceed with design and development of the CEV.

5.0 Risk Management

The CEV project, in compliance with NPR 8000.4, Risk Management Procedural Requirements, practices a Continuous Risk Management process that provides structured. management of all risks facing the project regardless whether they are based in safety, cost, schedule, or technical risk areas. Each CEV team member is actively engaged in identifying and logging all project risks in the risk database so that they can be coordinated and pro-actively resolved. Subsystem managers define the top risks associated with their subsystem and allocate mitigation resources as required. Risk Mitigation Plans are developed for each risk, and progress in carrying out those plans is reported, monitored, and controlled on a continuous basis. The monthly CEV Project-level Risk Board (comprised of the senior project leadership) reviews, integrates, and controls the risks from each subsystem and determines if these risks and mitigation strategies should be elevated to the top CEV project risk list and coordinated with the Constellation Program office. Named after the patterns that stars form in the night sky, the Constellation Program is responsible for developing the CEV, CLV, and related exploration architecture systems that will provide humans the capabilities necessary to travel and explore the solar system.

NASA has expended considerable time and resources in the formulation phase of the CEV project to best define requirements and risk factors to mission success. In May 2005, the ESAS was initiated, with one task, among others, to provide an assessment of the top-level CEV requirements. Further, the. ESAS laid the groundwork by defining the baseline technical content, cost, schedule, and principal risk factors. Since that time, a rigorous Constellation Program systems engineering and integration process has been established to control changes to missions, requirements, cost, schedule, and risk as these occur normally through the project formulation and development processes.

NASA has spent a year continuing to refine and mitigate concept risks through the combination of trades and analysis performed by NASA in-house teams and both CEV Phase 1 contractors. As a result of the ESAS and the ensuing work, the architecture and the top-level requirements for the CEV were chosen and made part of the Phase 2 competition. Additionally, NASA established an infra-agency CEV Smart Buyer Team which performed trade studies and design analyses that were used by the CEV Project Office to understand and verify the appropriateness of the requirements incorporated into the CEV Phase 2 solicitation and evaluation of proposals. The evolution of the Constellation systems, along with more clear definition of the CEV, allows NASA to select a single contractor at this time. Detailed design decisions are necessary to continue the development of the CEV, including contractor-specific design solutions and definitions of development risks.

Key aspects for managing contractual and schedule risks are incentives and control devices such as the use of Earned Value Management, which NASA has adopted into its contracting strategy. During DDT&E, NASA will use an end-item award fee. This makes all award fees subject to final determination that the product has been demonstrated to meet all requirements. The contractor will have incentives to identify risks early and to quickly and pro-actively mitigate them. This is a powerful tool for NASA and provides incentives to be successful on all elements of the project: cost (including life cycle costs), schedule, technical, and quality. There will be inherent motivation toward schedule performance by means of concluding each project milestone with an award fee determination. Since no provisional payments will be made, industry will not receive interim payments until the completion of an established project milestone. A slip in schedule will be reflected both in a delay in receipt of the interim payment and a lower evaluation score in the associated NASA evaluation.

In summary, the CEV project utilizes a structured process for managing all risks which encompasses safety, cost, schedule, or technical risk areas. Risk Mitigation Plans are developed for each risk, and progress of these risk mitigation plans is reported, monitored, and controlled on a continuous basis by project management. Risk integration is performed at all levels to ensure efficient, effective risk mitigation within the CEV Project and across the Constellation Program. Further, considerable work was done in the formulation phase to understand and characterize the risk trade space with various requirements and development options.

6.0 Summary

In accordance with Section 103 (a) of the *NASA Authorization Act of 2005,* NASA has clearly identified technical, cost, schedule, and safety risks and has plans to manage them. NASA has baselined an architecture that has mature technologies. Finally, the NASA CEV Project has complied with all relevant policies, regulations, and directives of the Agency.

The CEV design, development, and acquisition efforts are on track for the identified Agency milestones. Selection of a CEV Prime Contractor is a major step forward in the implementation of the *Vision for Space Exploration.* NASA has demonstrated a sound acquisition strategy that seeks commitment from industry for a design solution and to control LCC through competition and incentives. NASA is ready to execute its next step, "down-select" to a single Prime and award a contract in order to:

- Finalize NASA and contractor design solutions.
- Allow open communications with the contractor that is going to design and develop the CEV. Communication between Government and the Phase 1 industry teams is currently limited due to source selection constraints.
- Proceed to the design review milestones with a single contractor.

To date, NASA has received firm competitive prices from industry to complete development of the CEV. NASA has identified no technology issues. NASA has demonstrated its technical, cost, and schedule risk management planning and has mitigations, budget, controls, and assessments in place. Earned value and other cost controls and reporting requirements are in place on all Government and contract deliverables.

The combination of the knowledge gained from the ESAS, the Smart Buyer team, the work in the CEV Phase 1 contracts and Phase 2 proposals and processes for risk control and integration enables NASA to "down select" a single Prime contractor. Hence, NASA will be able to baseline an industry approach and commitment to meet the desired outcomes of the CEV project.

LETTER FROM GAO TO CHAIRMAN BOEHLERT

JULY 17, 2006

The Honorable Sherwood Boehlert
Chairman
The Honorable Bart Gordon
Ranking Minority Member
Committee on Science
House of Representatives

Subject: *NASA: Long-Term Commitment to and Investment in Space Exploration Program Requires More Knowledge*

The National Aeronautics and Space Administration (NASA) plans to spend nearly $230 billion over the next two decades implementing the *Vision for Space Exploration.* In January 2006, NASA publicly released its Exploration Systems Architecture Study (ESAS), which is an effort to identify the best architecture and strategy to implement the President's 2004 *Vision for Space Exploration* (Vision).[1] The cost estimate for implementing the ESAS through fiscal year 2011 exceeds $31 billion. The estimate through fiscal year 2018 is over $122 billion, and the estimate through fiscal year 2025 is nearly $230 billion.[2] These estimates include the architecture, robotic precursor missions, supporting technologies, and funding needed to service the International Space Station (ISS).[3] NASA plans to implement this architecture through a "go as you can afford to pay" approach, wherein lower-priority efforts would be deferred, descoped, or discontinued to allow NASA to stay within its available budget profile. This approach assumes NASA's budget will increase moderately to keep pace with inflation. Given the long-term fiscal imbalances that will challenge the entire Federal Government now and in the future, it would be prudent for NASA to establish a program that reduces the risk that significant additional funding, beyond moderate increases for inflation, will be required to execute the program.[4] Government leaders will have to make difficult decisions to resolve such challenges, and the debate over the potential cost and the Federal Government's role in implementing the Vision are emblematic of the challenges the Nation will need to resolve in the years ahead.

Because of the significance of this investment, competing demands on the federal discretionary budget, and the importance of the success of NASA's exploration program to the future of U.S. human space flight, you requested that we assess (1) the extent to which NASA has identified the architecture and costs necessary to implement the Vision, (2) whether NASA's exploration architecture cost estimates fit within the Agency's projected available budgets, and (3) the risks associated with NASA's acquisition strategy for the CEV project.

We presented our preliminary findings to your staff in May 2006. Because of your committee's interest in how NASA is implementing the *Vision for Space Exploration,* we are enclosing the full briefing that supported that May presentation with this report (see Encl. II), along with a summary of our findings and conclusions. We are recommending that the NASA Administrator modify the current CEV acquisition strategy to ensure that the Agency does not commit itself, and in turn the Federal Government, to a long-term contractual obligation prior to establishing a sound business case at the project's preliminary design review. In written comments, NASA non-concurred with our recommendation and stated that it has the appropriate level of knowledge to proceed with its current acquisition strategy. As a result of its nonconcurrence, we are including as a matter for congressional consideration that the Congress should consider restricting NASA's appropriations and obligations for the CEV project to only the amount of funding necessary to successfully complete the project's preliminary design review.

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[1] The ESAS architecture supports the development of a new Crew Exploration Vehicle (CEV), Crew Launch Vehicle (CLV), a Cargo Launch Vehicle (CaLV), and other supporting systems. The architecture also calls for various Research and Technology (R&T) and Robotic Lunar Exploration Program (RLEP) projects.

[2] All cost estimates related to the Vision are reported as inflated ("real year") dollars.

[3] NASA's cost estimate through 2011—$31.2 billion—included the costs of the R&T and RLEP projects needed to support the architecture. Its estimate for the first lunar landing—$104 billion—did not include $18 billion in funding for R&T and RLEP projects. To ensure consistency, the estimates for 2018 and 2025 are presented with R&T and RLEP funding included.

[4] GAO, *21st Century Challenges: Re-examining the Base of the Federal Government,* GAO–05–325SP (Washington, D.C.: Feb. 2005); *21st Century: Addressing Long-Term Fiscal Challenges Must Include a Re-examination of Mandatory Spending,* GAO–06–456T (Washington, D.C.: Feb. 15, 2006); and *Highlights of a GAO Forum: The Long-Term Fiscal Challenge,* GAO–05–282SP (Washington, D.C.: Feb. 1, 2005).

Background

The Vision includes plans to explore the Moon, Mars, and beyond.[5] The first step in implementing the Vision is to retire the Space Shuttle after completing assembly of the ISS by the end of the decade. NASA currently plans to retire the Space Shuttle in 2010, creating a potential gap in U.S. human space flight of up to four years before development of the CEV and the CLV is complete. Congress has voiced concern over the United States not having continuous access to space, and NASA has made it a priority to minimize the gap by accelerating the CEV project to have it in service as close to 2010 as possible. NASA's Exploration Systems Mission Directorate's (ESMD) Constellation program is responsible for the development of both the CEV and the CLV. NASA awarded concept development contracts for the CEV project to both Lockheed Martin and Northrop Grumman in July 2005 and plans to award a contract for design, development, production and sustainment in September 2006. That contract could extend through 2019. For the CLV, NASA plans to award a sole-source contract for the first stage of the CLV to ATK–Thiokol, the manufacturer of the Shuttle's Reusable Solid Rocket Motor, in October 2006. Also, the Agency plans to award Pratt & Whitney Rocketdyne, the developer of the Space Shuttle Main Engine (SSME) and J–2 engines, a sole-source contract for development of the J–2X engine in November 2006. These contractors are currently planning their respective efforts under interim contract arrangements. NASA has started in-house preliminary design work on the CLV upper stage structures and avionics and plans to begin awarding competitive contracts for production of these items in May 2007.

Despite many successes in the exploration of space, such as landing the Pathfinder and Exploration Rovers on Mars, the loss of life, unsuccessful missions, and unforeseen cost overruns have recently increased the level of concern over the benefits of such exploration, particularly with regard to human space flight activities. NASA has had difficulty bringing a number of projects to completion, including several efforts to build a second generation of reusable human space flight vehicle to replace the Space Shuttle. NASA has attempted several expensive endeavors such as the National Aero-Space Plane, the X–33 and X–34, and the Space Launch Initiative, among others. While these endeavors have helped to advance scientific and technical knowledge, none have completed their objective of fielding a new reusable space vehicle. We estimate that these unsuccessful development efforts have cost approximately $4.8 billion since the 1980s. The high cost of these unsuccessful efforts and the potential costs of implementing the Vision make it important that NASA achieve success in its new exploration program.

Our past work has shown that developing a sound business case, based on matching requirements to available and reasonably expected resources before committing to a new product development effort, reduces risk and increases the likelihood of successful outcomes.[6] At the heart of a business case is a knowledge-based approach to product development that is a best practice among leading commercial firms and successful government system developers. For a program to increase its chances of delivering a successful product, high levels of knowledge should be demonstrated before managers make significant program commitments. In essence, knowledge supplants risk over time. This building of knowledge can be described as three levels that should be attained over the course of the program:

(1) At program start, the customer's needs should match the developer's available resources in terms of availability of mature technologies, time, human capital, and funding.

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[5] The Vision includes a return to the Moon that is intended ultimately to enable future exploration of Mars and other destinations. To accomplish this, NASA initially plans to (1) complete its work on the International Space Station by 2010, fulfilling its commitment to 15 international partner countries; (2) begin developing a new manned exploration vehicle to replace the Space Shuttle; and (3) return to the Moon no later than 2020 in preparation for future, more ambitious missions.

[6] Examples of our best practices reports include GAO, *Best Practices: Using a Knowledge-Based Approach to Improve Weapon Acquisition,* GAO–04–386SP (Washington, DC.: Jan. 2004); *Space Acquisitions: Committing Prematurely to the Transformational Satellite Program Elevates Risks for Poor Cost, Schedule, and Performance Outcomes,* GAO–04–71R (Washington, D.C.: Dec. 4, 2003); *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes,* GAO–02–701 (Washington, D.C.: Jul. 15, 2002); and *Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes,* GAO–01–288 (Washington, DC.: Mar. 8, 2001).

(2) Midway through development, the product's design should be stable and demonstrate that it is capable of meeting performance requirements.
(3) By the time of the production decision, the product must be shown to be producible within cost, schedule, and quality targets, and have demonstrated its reliability.

Our work has shown that programs that have not attained the level of knowledge needed to support a sound business case have been plagued by cost overruns, schedule delays, decreased capability, and overall poor performance. With regard to NASA, we have reported that in some cases the Agency's failure to define requirements adequately and develop realistic cost estimates—two key elements of a business case—resulted in projects costing more, taking longer, and achieving less than originally planned.

Summary

Although NASA is continuing to refine its exploration architecture cost estimates, the Agency cannot at this time provide a firm estimate of what it will take to implement the architecture. The absence of firm cost estimates is mainly due to the fact that the program is in the early stages of its life cycle. According to NASA cost-estimating guidance, early life cycle phase estimates are generally based upon parametric models, which use data from projects with similar attributes to predict cost because there are usually many unknowns and actual cost or performance data are not available. NASA preliminarily identified the resources needed to implement the architecture as outlined in the architecture study primarily through the use of such models. NASA conducted a cost risk analysis of its preliminary estimates through fiscal year 2011. On the basis of this analysis and through the addition of programmatic reserves (20 percent on all development and 10 percent on all production costs), NASA is 65 percent confident that the actual cost of the program will either meet or be less than its estimate of $31.2 billion through fiscal year 2011. For the cost estimates for beyond 2011, when most of the cost risk for implementing the architecture will be realized, NASA has not applied a confidence level distinction. Since NASA released its preliminary estimates, the Agency has continued to make architecture changes. For example, following the issuance of the architecture study, NASA conducted several analysis cycles during which various aspects of the architecture have evolved, such as the diameter of the CEV, the engine used to support the upper stage of the CLV, and the size of the Reusable Solid Rocket Booster on the CLV. While these changes, and others, are appropriate for this phase of the program, when concepts are still being developed, they leave the Agency in the position of being unable to firmly identify program requirements and needed resources, which can also be expected at this phase of the program. According to NASA officials, once they receive more detailed contractor inputs, the Agency will be able to produce higher-fidelity estimates of program cost. NASA plans to commit to a firm cost estimate at the preliminary design review (PDR) in 2008, when the program's requirements, design, and schedule will all be baselined.

NASA will be challenged to implement the architecture recommended in the study within its projected budget. Whether using the architecture study estimates of funds available or NASA's Fiscal Year 2007 Budget Submission for ESMD that was based on the architecture study cost estimates, there are years when NASA does not have sufficient funding to implement the architecture. Some yearly shortfalls exceed $1 billion, while in other years the funding available exceeds needed resources. NASA maintains that the architecture could be implemented within the projected available budgets through fiscal year 2011 when funding is considered cumulatively. In addition, NASA preliminarily projects multibillion-dollar shortfalls for ESMD in all fiscal years from 2014 to 2020, with an overall deficit through 2025 of over $18 billion. In the short-term, NASA is attempting to address this problem within the Constellation program by redirecting funds to that program from other ESMD activities to provide a significant surplus for fiscal years 2006 and 2007 to cover projected shortfalls beginning in fiscal year 2009. In addition, the Constellation program has requested more funds than required for its projects in several early years to cover shortfalls in later years. For example, the Exploration Communication and Navigation Systems project within the Constellation program plans to roll over $56.2 million from the fiscal year 2007 budget to make up for budget shortfalls in fiscal years 2008, 2009, and 2010. NASA officials stated the identified budget phasing problem could worsen given that changes made to the exploration architecture following issuance of the study will likely add to the near-term development costs, where the funding is already constrained. In addition, NASA's estimates beyond 2010 are based upon a surplus of well over $1 billion in fiscal year 2011 due to the retirement of the Space Shuttle fleet in 2010. However, NASA officials said the costs for retiring the Space Shuttle and transitioning to the new program are not fully understood, and thus the expected surplus could be less than anticipated.

NASA's current acquisition strategy for the CEV places the project at risk of significant cost overruns, schedule delays, and performance shortfalls because it commits the government to a long-term product development effort before establishing a sound business case. NASA plans to award a contract for the design, development, production, and sustainment of the CEV in September 2006—before it has developed key elements of a sound business case, including well-defined requirements, a preliminary design, mature technology, and firm cost estimates. The period of performance for the contract scheduled for award in September 2006 will extend through at least 2014, with the possibility of extending through 2019. This contract will comprise all design, development, and test and evaluation activities, including production of ground and flight test articles and at least four operational CEVs. Although NASA is committing to a long-term contract, it will not have the elements of a sound business case in place until the project level PDR in fiscal year 2008. Awarding a contract for design, development, production, and sustainment of the project as NASA has planned places the CEV project at increased risk of cost growth, schedule delays, and performance shortfalls. At PDR, NASA will likely (a) have the increased knowledge necessary to develop a sound business case that includes high-fidelity, engineering-based estimates of life cycle cost for the CEV project, (b) be in a better position to commit the government to a long-term effort, and (c) have more certainty in advising Congress on required resources.

Implementing the Vision over the coming decades will require hundreds of billions of dollars and a sustained commitment from multiple Administrations and Congresses over the length of the program. The realistic identification of the resources needed to achieve the Agency's short-term goals would provide support for such a sustained commitment over the long-term. With a range of federal commitments binding the fiscal future of the United States, competition for resources within the Federal Government will only increase over the next several decades. Consequently, it is incumbent upon NASA to ensure that it is wisely investing its existing resources. As NASA begins to implement the Vision with several key acquisition decisions planned to occur this fall, it will be essential that the Agency ensure that the investment decisions it is making are sound and are based upon high levels of knowledge. NASA should make the prudent decision now to ensure that it has attained the appropriate level of knowledge to support a sound business case before it commits to the project. However, under the current acquisition strategy for CEV, key knowledge—including well-defined requirements, a preliminary design, mature technology, and firm cost estimates—will not be known until over a year after the expected contract award date. Nevertheless, NASA plans to commit the government to a long-term contract. This approach increases the risk that the project will encounter significant cost overruns, schedule delays, and decreased capability. Given the Nation's fiscal challenges and those that exist within NASA, the availability of significant additional resources to address such issues, should they occur, is unlikely. With the impending decisions pertaining to the CEV, NASA has the opportunity to establish a firm foundation for the entire Constellation program by ensuring that the appropriate level of knowledge is available before proceeding with its acquisition strategy and committing the government to a long-term design, development, and production effort.

Recommendation for Executive Action

Because of the importance of the CEV project to NASA's overall implementation of the Vision, NASA should focus on ensuring that its acquisition approach for the CEV project does not place the government at risk by committing to a long-term design and development effort without the knowledge needed to make wise investment decisions. We therefore recommend that the NASA Administrator modify the current CEV acquisition strategy to ensure that the Agency does not commit itself, and in turn the Federal Government, to a long-term contractual obligation prior to demonstrating, through the establishment of a sound business case at the project's preliminary design review, that the project is affordable and executable.

Matter for Congressional Consideration

Based on its response to our report, it appears that NASA plans to proceed with its acquisition strategy for the CEV and award a long-term contract for the project, although it continues to lack sufficient knowledge and a sound business case for doing so. Congress is currently being asked to approve NASA's fiscal year 2007 funding request and will be asked to approve fiscal year 2008 and perhaps the fiscal year 2009 funding requests for the CEV project before NASA has demonstrated such knowledge and has provided evidence, based on that knowledge, that the project will be executable within existing and expected resources. In light of the fact that NASA plans to award the contract for the CEV in September 2006, Congress should consider restricting annual appropriations and limiting NASA's obligations for the CEV project to only the amount of funding necessary to support activities needed to successfully complete the project's preliminary design review.

Agency Comments and Our Evaluation

In written comments on a draft of this report (see Encl. I), NASA non-concurred with our recommendation that it modify the current CEV acquisition strategy to ensure that the Agency does not commit itself, and in turn the Federal Government, to a long-term contractual commitment prior to establishing a sound business case at the project's preliminary design review. NASA stated that it has the appropriate level of knowledge to proceed with its acquisition plan to "down select" to a single Crew Exploration Vehicle prime contractor in September 2006. NASA added that it is maximizing competition by soliciting from industry a development, production, and management approach with an emphasis on life cycle cost. In the area of technology maturity, NASA stated that it has a plan and process in place to address the Thermal Protection and Landing subsystems technology risks through in-house development work and collaboration with the prime contractor. NASA also noted that during its design, development, and test and evaluation effort, the Agency will be using an end-item award fee, which would make all award fees subject to a final evaluation to determine how well the product met requirements, including cost and schedule.

The CEV acquisition strategy is not knowledge-based in that it calls for maturing technologies, designing systems, and preparing for initial production concurrently—an approach that our work has shown carries the increased risk of cost and schedule overruns and decreased technical capability. Therefore, we disagree with NASA's statement that it has the appropriate level of knowledge to proceed with its current acquisition strategy and award a long-term contract for the project prior to obtaining sufficient knowledge. Specifically:

- In its response, NASA suggests that there would be no benefit in retaining two prime contractors for the CEV project through the preliminary design review and that the best return on its investment would be gained by down-selecting to one contractor and awarding the contract in September 2006. Contrary to NASA's response, addressing our recommendation would not preclude the Agency from down-selecting to one contractor. The thrust of our recommendation is that NASA should lessen the government's obligation to the project at such an early stage when realistic cost estimates have yet to be established and requirements are not fully defined, and therefore limit the scope of the contract to activities needed to successfully complete the preliminary design review. At that point the project should have in place a sound business case for proceeding and hence be in a better position to justify continued investment. Implementation of the recommendation could be accomplished through various means, including by retaining two contractors through the preliminary design review and awarding a contract at that time or by down-selecting as planned in September 2006 and limiting the scope of the contract as described above.
- NASA's suggestion that it is maximizing competition by soliciting from industry its development, production, and management approach and that it will receive firm competitive prices from industry for completion of development and demonstration of two vehicles has little basis. First, while the current structure will allow for competition in the short-term, the benefits of such competition will be short-lived. Without well-defined requirements, mature technologies, an approved preliminary design, and realistic cost estimates, NASA has insufficient information to ensure that it is obtaining firm competitive prices for the work conducted for the entirety of Schedule A—especially for activities beyond the project's preliminary design review.

  Because NASA continues to refine the project's requirements, as demonstrated by the numerous changes to the exploration architecture as discussed in our report, it cannot provide a firm estimate of project cost. Without such information, it will likely be difficult for NASA to establish realistic "not-to-exceed" prices for Schedule B activities. Under the current strategy, NASA will not have high-fidelity, engineering-based estimates of life cycle costs for the CEV until the preliminary design review. As outlined in this report, projects with cost estimates based on early, evolving designs and top-level requirements are at increased risk of cost growth relative to estimates based on mature designs and detailed requirements—which could be achieved at the preliminary design review. According to NASA, it plans to obtain this and further knowledge about program cost, schedule, and risk elements following the contract award and in conjunction with the contractor. In the absence of such information, it is not clear how NASA can substantiate its statement that it has the knowledge necessary to commit to activities beyond the project's preliminary design review. Further, it cannot provide Congress with assurance of the appropriateness of requested funding for the project.

- NASA stated that its current acquisition strategy for the CEV minimizes the government's obligation during development by dividing the CEV contract into three separate schedules. All three schedules, however, will be awarded in September 2006 as part of one contract. Although NASA plans to include language in the negotiated CEV contract to state that the minimum quantity under Schedule B will not be applicable until that schedule's period of performance begins in 2009—a step that would lessen the government's obligation during production—it will continue to be responsible for all Schedule A activities at the time of contract award. These activities include all design, development, and test and evaluation activities, as well as the production of two operational vehicles. Contractually obligating the government to even these Schedule A activities, before it has established a sound business case to support such a commitment, is not in line with our knowledge-based approach and is ultimately not in the best interest of the government.
- NASA's investment in identifying and maturing the Thermal Protection and Landing Subsystems is a step in the right direction to ensure that these technologies are mature and available when needed. NASA has no guarantee, however, that these critical technologies will be mature by the time of the project's preliminary design review—the point at which our work has shown that technologies should be mature in order to decrease the risk of cost and schedule growth. NASA's proposed commitment to the project for activities beyond the preliminary design review before retiring these technology risks increases the likelihood that the project will experience schedule delays and cost overruns.
- NASA maintains that program risks have been marginalized and that the Agency will utilize incentives, including end-item award fees, to ensure contractor performance. NASA suggests that the incentives it plans to use in the form of end-item award fees will be a powerful tool for meeting cost schedule, technical, and quality goals. The use of these tools, however, does not compensate for proceeding with a risky acquisition, nor do they lessen NASA's responsibility to implement an executable program from the start. For them to function as intended, NASA needs to address the more fundamental issues related to its acquisition strategy, including its lack of a sound business case for the CEV project.
- Finally, the use of cost-reimbursable contracting, while appropriate for early development and design efforts, places most of the cost risk for the project on the government. Given the nature of this effort, it is likely that the project will change significantly as it moves forward. Therefore, any scope changes or schedule slips could translate into additional contract cost for NASA. Such cost impacts could be minimized if NASA limited its contractual obligation to those activities needed to achieve a successful preliminary design review, as we recommended. In addition, limiting the scope of the CEV contract would allow both NASA and Congress to assess the project's progress at the preliminary design review and to decide if continued investment in the project is prudent and in the best interest of the government.

It is important to note that Congress will continue to be asked to make funding commitments in advance of CEV project events that would demonstrate that the project has the knowledge necessary to support a sound business case. Specifically, NASA's funding request for fiscal years 2007 and 2008 are scheduled to be approved before the CEV holds its preliminary design review. Since the preliminary design review is currently scheduled for March 2008, this may also be the case for fiscal year 2009. Congress should safeguard against a situation in which contractual and budget decisions could hinder its ability to tie further investments in the CEV project to demonstrated progress at the preliminary design review. As such, we have included a matter for congressional consideration.

We also received technical comments from NASA, which have been addressed in the report, as appropriate.

Scope and Methodology

To assess the extent to which NASA has identified the architecture and costs necessary to implement the Vision and whether NASA's exploration architecture cost estimates fit within the Agency's projected available budgets, we reviewed and analyzed NASA's Exploration Systems Architecture Study, fiscal year 2007 budget request, ground rules and assumptions provided from the Constellation program to project level management estimators to perform the bottom up review, guidance for use in preparing the fiscal year 2008 budget request, NASA cost-estimating guidance in the NASA Cost Estimating Handbook, and congressional hearings and testimonies pertaining to NASA and the Vision. We also conducted interviews with NASA headquarters officials from the Cost Analysis Division, the Exploration Systems Mission Directorate, and Constellation program officials, Constellation program and CEV project officials at Johnson Space Center; CLV project officials at Marshall Space Flight Center; and cost analysts from the Kennedy Space Center. During these interviews, we discussed the methodologies used in preparing the ESAS and subsequent cost estimates, architecture changes after the ESAS and the trades being considered, budgeting issues, and procurement strategies and activities.

To assess the risks associated with NASA's acquisition strategy for the CEV project, we reviewed and analyzed CEV project documentation, including draft project plans, draft requirements documents, technology development plans, documentation included in the contract request for proposals, and past NASA human space flight acquisition programs. We compared NASA's plans for the CEV with criteria contained in GAO best practices work on systems acquisition. We also conducted interviews with NASA headquarters officials from the Exploration Systems Mission Directorate and Constellation Systems officials, Constellation program and CEV project officials at Johnson Space Center, and CLV project officials at Marshall Space Flight Center.

We conducted our work from January 2006 to May 2006 in accordance with generally accepted government auditing standards.

As agreed with your offices, unless you announce its contents earlier, we will not distribute this report further until 10 days from its date. At that time, we will send copies of the report to NASA's Administrator and interested congressional committees. We will also make copies available to others upon request. In addition, the report will be available at no charge on GAO's web site at *http://www.gao.gov.*

Should you or your staff have any questions on matters discussed in this report, please contact me at (202) 512-4841 or *lia@gao.gov.* Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Principal contributors to this report were James L. Morrison, Assistant Director; Rick Cederholm; Shelby S. Oakley; Guisseli Reyes; Sylvia Schatz; and John S. Warren, Jr.

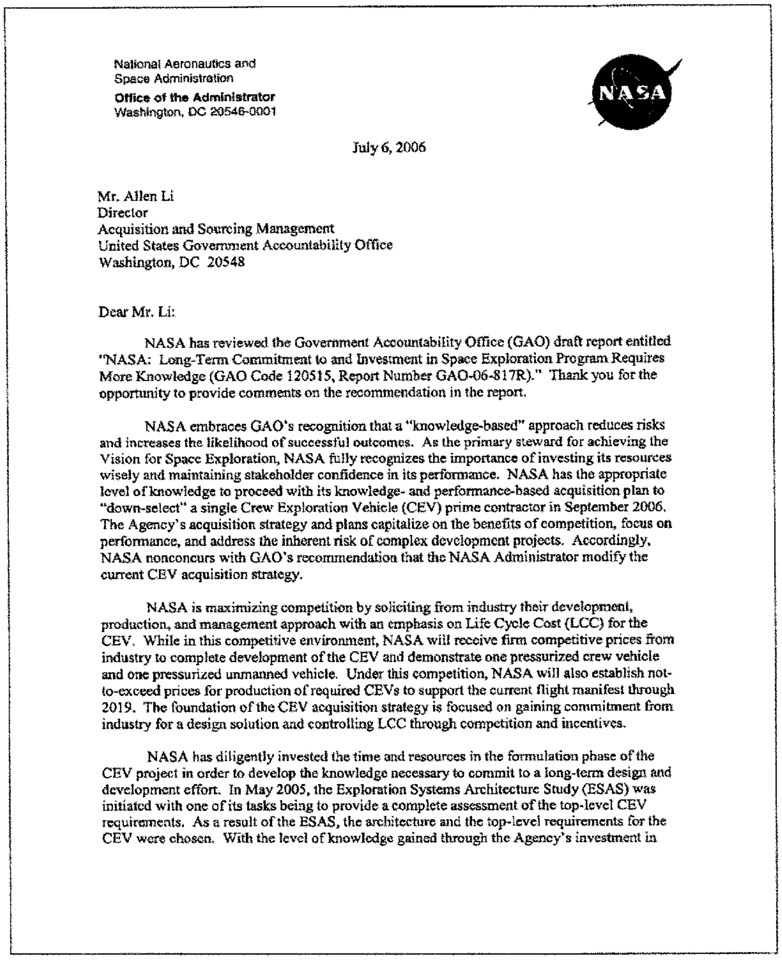
Allen Li

Allen Li
Director
Acquisition and Sourcing Management

Enclosures

Enclosure I

Comments from the National Aeronautics and Space Administration



National Aeronautics and
Space Administration
Office of the Administrator
Washington, DC 20546-0001

July 6, 2006

Mr. Allen Li
Director
Acquisition and Sourcing Management
United States Government Accountability Office
Washington, DC 20548

Dear Mr. Li:

NASA has reviewed the Government Accountability Office (GAO) draft report entitled "NASA: Long-Term Commitment to and Investment in Space Exploration Program Requires More Knowledge (GAO Code 120515, Report Number GAO-06-817R)." Thank you for the opportunity to provide comments on the recommendation in the report.

NASA embraces GAO's recognition that a "knowledge-based" approach reduces risks and increases the likelihood of successful outcomes. As the primary steward for achieving the Vision for Space Exploration, NASA fully recognizes the importance of investing its resources wisely and maintaining stakeholder confidence in its performance. NASA has the appropriate level of knowledge to proceed with its knowledge- and performance-based acquisition plan to "down-select" a single Crew Exploration Vehicle (CEV) prime contractor in September 2006. The Agency's acquisition strategy and plans capitalize on the benefits of competition, focus on performance, and address the inherent risk of complex development projects. Accordingly, NASA nonconcurs with GAO's recommendation that the NASA Administrator modify the current CEV acquisition strategy.

NASA is maximizing competition by soliciting from industry their development, production, and management approach with an emphasis on Life Cycle Cost (LCC) for the CEV. While in this competitive environment, NASA will receive firm competitive prices from industry to complete development of the CEV and demonstrate one pressurized crew vehicle and one pressurized unmanned vehicle. Under this competition, NASA will also establish not-to-exceed prices for production of required CEVs to support the current flight manifest through 2019. The foundation of the CEV acquisition strategy is focused on gaining commitment from industry for a design solution and controlling LCC through competition and incentives.

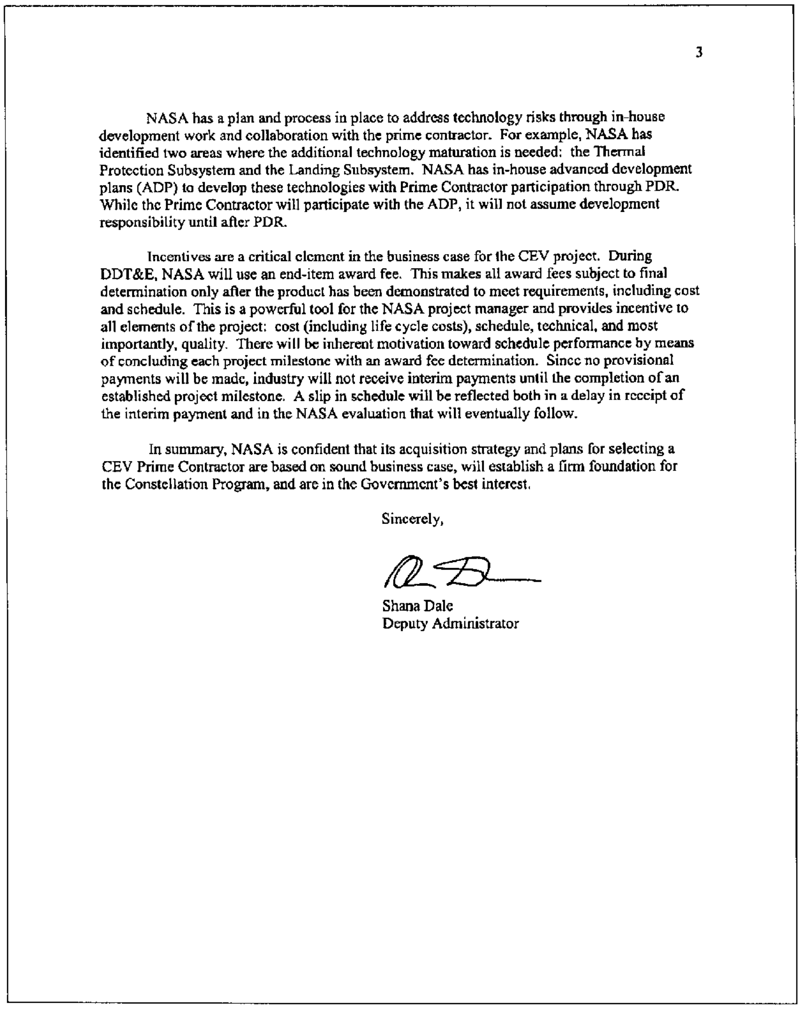
NASA has diligently invested the time and resources in the formulation phase of the CEV project in order to develop the knowledge necessary to commit to a long-term design and development effort. In May 2005, the Exploration Systems Architecture Study (ESAS) was initiated with one of its tasks being to provide a complete assessment of the top-level CEV requirements. As a result of the ESAS, the architecture and the top-level requirements for the CEV were chosen. With the level of knowledge gained through the Agency's investment in the ESAS and with its acquisition strategy, NASA perceives no benefit in retaining two prime contractors through Preliminary Design Review (PDR) at an estimated cost of $1 billion each. Instead, NASA has determined that a better return on its investment would be gained by competitively issuing two Phase 1 CEV prime contracts for conceptual design and trade studies against the ESAS architecture for an estimated cost of $46 million each and including the CEV requirements as part of the CEV Phase 2 contract competition. Additionally, NASA established an intra-agency CEV Smart Buyer team which performed trade studies and design analyses that were used by the CEV Project Office to understand and verify the appropriateness of the requirements incorporated into the CEV Phase 2 solicitation and evaluation of proposals. With knowledge gained from ESAS, the Smart Buyer team, and the CEV Phase 1 contracts, NASA is now in a sound position to "down-select" a single prime contractor, thereby base-lining an industry approach and commitment to meet the desired outcomes of the CEV project.

NASA's business approach is consistent with GAO's knowledge-based recommendation and recognition that knowledge replaces risk over time. The CEV acquisition strategy contains separate contract schedules and design reviews which are equivalent to GAO's defined Knowledge Points. NASA's acquisition strategy minimizes the Government's obligation during development by dividing the CEV contract into three different schedules:

- Schedule A for Design Development, Test, and Evaluation (DDT&E).
- Schedule B for production beyond Schedule A.
- Schedule C for sustaining activities during production and operation.

Schedule A is authorized at contract award and continues through the first flight demonstration of each design variant of the CEV. Schedule A executes the formulation phase of the project such that NASA can utilize the contractor's knowledge to develop a set of validated requirements, including component specifications and mature technologies by the project's PDR. The current CEV strategy will allow NASA and the contractor to attain further appreciation and knowledge about the project and its required resources to provide firm cost, schedule, and risk elements. At this point, the Non-Advocacy Review (NAR) is typically scheduled immediately following the baseline of the project's preliminary design.

Authorization of Schedule B is planned post PDR, NAR, and the Critical Design Review (CDR) and is currently limited to a minimum production quantity of two units. Authorization of Schedule C is planned at approximately the same time as Schedule B. The CEV strategy does not commit the Agency to any production until the NAR milestone is met. Additionally, utilizing Delivery Orders (Indefinite Delivery Indefinite Quantity) for Schedules B and C provides NASA with the ability to order only the units and the sustaining engineering necessary, with appropriate incentives, when the requirements and costs are better understood by NASA and industry. NASA will not commit to Schedule B or C activities until it is time to implement that portion of the contract. To mitigate concerns about the minimum production quantity of two units under the production contract (Schedule B), language will be included in the final negotiated CEV contract that will make explicit that the minimum quantity will not be applicable until the period of performance of Schedule B begins. First production orders are planned to be placed in the fall of 2009, nine months after the baseline of the CEV's critical design or CDR (Knowledge Point 3).



NASA has a plan and process in place to address technology risks through in-house development work and collaboration with the prime contractor. For example, NASA has identified two areas where the additional technology maturation is needed: the Thermal Protection Subsystem and the Landing Subsystem. NASA has in-house advanced development plans (ADP) to develop these technologies with Prime Contractor participation through PDR. While the Prime Contractor will participate with the ADP, it will not assume development responsibility until after PDR.

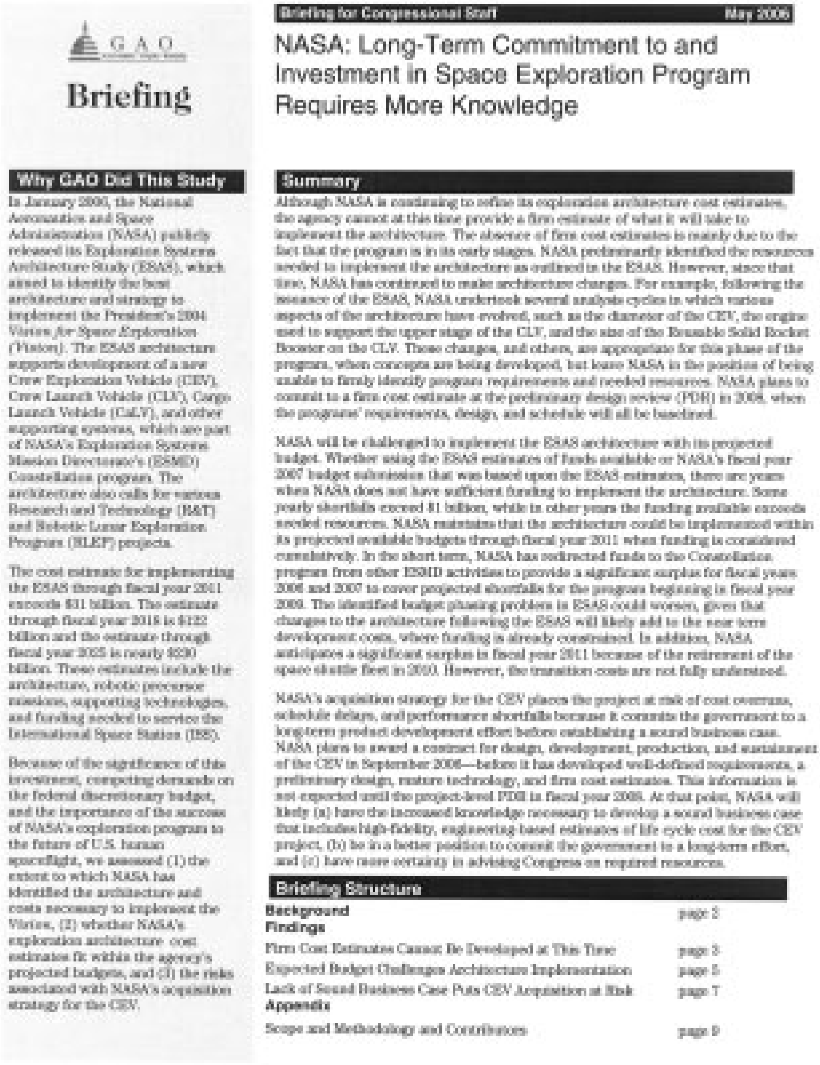
Incentives are a critical element in the business case for the CEV project. During DDT&E, NASA will use an end-item award fee. This makes all award fees subject to final determination only after the product has been demonstrated to meet requirements, including cost and schedule. This is a powerful tool for the NASA project manager and provides incentive to all elements of the project: cost (including life cycle costs), schedule, technical, and most importantly, quality. There will be inherent motivation toward schedule performance by means of concluding each project milestone with an award fee determination. Since no provisional payments will be made, industry will not receive interim payments until the completion of an established project milestone. A slip in schedule will be reflected both in a delay in receipt of the interim payment and in the NASA evaluation that will eventually follow.

In summary, NASA is confident that its acquisition strategy and plans for selecting a CEV Prime Contractor are based on sound business case, will establish a firm foundation for the Constellation Program, and are in the Government's best interest.

Sincerely,

Shana Dale
Deputy Administrator

Enclosure II



GAO

Briefing

Briefing for Congressional Staff May 2006

NASA: Long-Term Commitment to and Investment in Space Exploration Program Requires More Knowledge

Why GAO Did This Study

In January 2006, the National Aeronautics and Space Administration (NASA) publicly released its Exploration Systems Architecture Study (ESAS), which aimed to identify the best architecture and strategy to implement the President's 2004 *Vision for Space Exploration* (*Vision*). The ESAS architecture supports development of a new Crew Exploration Vehicle (CEV), Crew Launch Vehicle (CLV), Cargo Launch Vehicle (CaLV), and other supporting systems, which are part of NASA's Exploration Systems Mission Directorate's (ESMD) Constellation program. The architecture also calls for various Research and Technology (R&T) and Robotic Lunar Exploration Program (RLEP) projects.

The cost estimate for implementing the ESAS through fiscal year 2011 exceeds $31 billion. The estimate through fiscal year 2018 is $122 billion and the estimate through fiscal year 2025 is nearly $230 billion. These estimates include the architecture, robotic precursor missions, supporting technologies, and funding needed to service the International Space Station (ISS).

Because of the significance of this investment, competing demands on the federal discretionary budget, and the importance of the success of NASA's exploration program to the future of U.S. human spaceflight, we assessed (1) the extent to which NASA has identified the architecture and costs necessary to implement the Vision, (2) whether NASA's exploration architecture cost estimates fit within the agency's projected budgets, and (3) the risks associated with NASA's acquisition strategy for the CEV.

Summary

Although NASA is continuing to refine its exploration architecture cost estimates, the agency cannot at this time provide a firm estimate of what it will take to implement the architecture. The absence of firm cost estimates is mainly due to the fact that the program is in its early stages. NASA preliminarily identified the resources needed to implement the architecture as outlined in the ESAS. However, since that time, NASA has continued to make architecture changes. For example, following the issuance of the ESAS, NASA undertook several analysis cycles in which various aspects of the architecture have evolved, such as the diameter of the CEV, the engine used to support the upper stage of the CLV, and the size of the Reusable Solid Rocket Booster on the CLV. These changes, and others, are appropriate for this phase of the program, when concepts are being developed, but leave NASA in the position of being unable to firmly identify program requirements and needed resources. NASA plans to commit to a firm cost estimate at the preliminary design review (PDR) in 2008, when the programs' requirements, design, and schedule will all be baselined.

NASA will be challenged to implement the ESAS architecture with its projected budget. Whether using the ESAS estimates of funds available or NASA's fiscal year 2007 budget submission that was based upon the ESAS estimates, there are years when NASA does not have sufficient funding to implement the architecture. Some yearly shortfalls exceed $1 billion, while in other years the funding available exceeds needed resources. NASA maintains that the architecture could be implemented within its projected available budgets through fiscal year 2011 when funding is considered cumulatively. In the short term, NASA has redirected funds to the Constellation program from other ESMD activities to provide a significant surplus for fiscal years 2006 and 2007 to cover projected shortfalls for the program beginning in fiscal year 2009. The identified budget phasing problem in ESAS could worsen, given that changes to the architecture following the ESAS will likely add to the near-term development costs, where funding is already constrained. In addition, NASA anticipates a significant surplus in fiscal year 2011 because of the retirement of the space shuttle fleet in 2010. However, the transition costs are not fully understood.

NASA's acquisition strategy for the CEV places the project at risk of cost overruns, schedule delays, and performance shortfalls because it commits the government to a long-term product development effort before establishing a sound business case. NASA plans to award a contract for design, development, production, and sustainment of the CEV in September 2006—before it has developed well-defined requirements, a preliminary design, mature technology, and firm cost estimates. This information is not expected until the project-level PDR in fiscal year 2008. At that point, NASA will likely (a) have the increased knowledge necessary to develop a sound business case that includes high-fidelity, engineering-based estimates of life cycle cost for the CEV project, (b) be in a better position to commit the government to a long-term effort, and (c) have more certainty in advising Congress on required resources.

Briefing Structure

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Background

Implementing the Vision

NASA plans to bring the President's *Vision* to reality over the next several decades by

- conducting exploration activities in low-Earth orbit; for example, flying the space shuttle to complete assembly of the ISS;
- exploring beyond low-Earth orbit; for example, establishing sustained exploration of the moon and Mars;
- developing transportation that supports exploration; for example, building crew exploration vehicles; and
- pursuing opportunities for international and commercial participation.

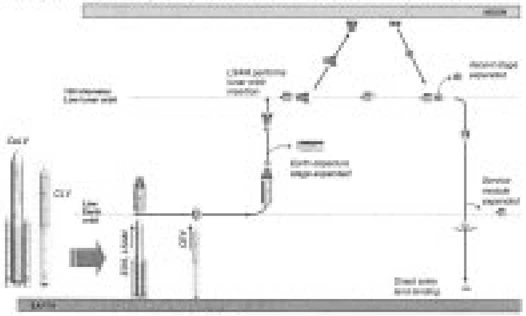
Exploration Contracts

NASA awarded concept development contracts to both Lockheed Martin and Northrop Grumman for the CEV project in July 2005. NASA plans to down-select to one contractor and award a contract for development, production, and sustainment of the CEV in September 2006. That contract could extend through 2019.

NASA plans to award a sole-source contract for the first stage of the CLV to ATK-Thiokol, the manufacturer of the Shuttle's Reusable Solid Rocket Motor, in October 2006. Also, the agency plans to award Pratt & Whitney Rocketdyne, the developer of the Space Shuttle Main Engine (SSME) and J-2 engines, a sole-source contract for development of the J-2X engine in November 2006. These contractors are currently planning their respective efforts under interim contract arrangements. NASA has started in-house preliminary design work on the CLV upper stage structures and avionics and plans to begin awarding competitive contracts for production of these items in May 2007.

Original Exploration Systems Architecture Study Overview

The ESAS outlined the recommended architecture and strategy for implementation of the *Vision*. The primary vehicles and elements of the architecture include the CEV, the CLV, the CaLV that includes the Earth Departure Stage (EDS), and the Lunar Surface Access Module (LSAM). The diagram below outlines a launch mission for crew and cargo, utilizing rendezvous locations in low-Earth and low-lunar orbits.



Source: NASA.

The original ESAS architecture is described below. Changes made to the architecture since the release of ESAS are described in later sections.

CEV: The CEV is a reusable, Apollo-derived cone-shaped capsule launched atop the CLV. The CEV consists of a Command Module (CM), a Service Module (SM), and a Launch Abort System (LAS). The CEV is sized at 5.5 meter diameters for lunar polar missions carrying a crew of four, and is also reconfigurable to accommodate up to six crew members for missions to ISS. The vehicle uses a Low Impact Docking System (LIDS) for ISS and lunar missions. The vehicle is reusable for up to 10 missions and will land on land with a water landing as a backup. The SM utilizes a pressure-fed liquid oxygen (LOX)/methane propulsion system.

CLV: The CLV consists of a shuttle-derived four-segment Reusable Solid Rocket Booster (RSRB) first stage and a newly designed upper stage with one modified, and now expendable, SSME. It will launch 25 metric tons to low-Earth orbit and serve as the long-term crew launch capability for the United States.

CaLV: The CaLV will use a heritage shuttle external tank-derived LOX/liquid hydrogen core stage propelled by five redesigned SSMEs. Attached to this core stage are two newly developed five-segment RSRBs, allowing over 100 metric tons to be launched to low-Earth orbit. The upper stage, which also serves as the EDS, uses an external tank-derived LOX/liquid hydrogen system and will employ two Saturn-derived J-2 engines.

LSAM: The LSAM is an expendable two-stage module launched atop the CaLV. The descent stage will utilize a LOX/liquid hydrogen propulsion system while the ascent stage will use a pressure-fed LOX-methane propulsion system. A crew cabin will be located on the ascent stage and will have an airlock to allow docking with the CEV. The LSAM will be able to land at any location on the lunar surface and will house a four-member crew for up to 7 days.

Enclosure II

Cost Estimating

Cost-Estimating Process

NASA's *Cost Estimating Handbook* outlines cost-estimating processes in relation to acquisition life cycle phases.

- In Pre-Phase A, there are many unknowns. At this point, the most effective cost-estimating approach is a parametric or analogous methodology, i.e., data from projects with similar attributes is used to predict the cost.
- In Phase A, conceptual designs are better defined and a better understanding of the system requirements and technical risks exists. But, parametric or analogous cost-estimating techniques are still used, because detailed data may still be unavailable.
- In Phase B, system designs are defined below the subsystem level. At this point, estimating methodologies evolve to more detailed parametric or engineering buildup estimates supported by technical experts. By the end of Phase B, specific data are available to prepare a full life cycle cost estimate.
- In Phases C and D, cost estimates are refined to include actual data. At this point, the preferred cost methodology is an engineering buildup based on the lowest level of detail available, including overhead, labor, and material costs.

Firm Cost Estimates Cannot Be Developed at This Time

NASA's cost estimates for implementing its exploration architecture are preliminary—a fact that NASA has acknowledged since the ESAS was publicly released. As part of the ESAS effort, NASA laid out the cost estimates for implementing the recommended architecture. Because the ESAS effort was an early life cycle activity, Pre-Phase A, the majority of the individual estimates were based upon parametric models, with little actual data.

The ESAS process evaluated the cost of various alternative exploration architectures based upon high-level program requirements. The recommended architecture costs totaled

- over $31 billion dollars through fiscal year 2011,
- over $122 billion through fiscal year 2018, and
- close to $230 billion through fiscal year 2025.[1]

NASA conducted a cost risk analysis of the estimates through fiscal year 2011. This analysis provided a 65 percent confidence level for the estimate (i.e., NASA is 65 percent certain that the actual cost of the program will either meet or be less than the estimate). To obtain this level of confidence in the estimates, NASA included programmatic reserves—20 percent on all development and 10 percent on all production costs. NASA only conducted the risk analysis through the first flight date of the CEV at the time of ESAS—2011—leaving the estimates through 2018 and 2025, when most of the cost risk for implementing the architecture will be realized, with no confidence level distinction. According to NASA officials, the cost risk analysis lacked quality because of the evolving nature of the requirements for the architecture and the compressed time frames with which they had to conduct the analysis. According to NASA officials, once they receive more detailed contractor inputs, the agency will be able to produce higher-fidelity estimates of program cost. NASA has stated that it would not commit to a cost estimate for implementing the exploration architecture until the Constellation program's PDR, which will occur in late fiscal year 2008. At that time, the requirements, design, schedule, and cost will all be baselined.

NASA refined the architecture several times since ESAS. As a result of these changes, the costs associated with the architecture have also changed. As part of the fiscal year 2007 budget formulation process, NASA made two major changes to plans laid out in the ESAS. First, the requirement for use of a LOX/methane engine on the CEV service module—a high-risk development—was removed, and the approach for meeting the propulsion requirement was left to the discretion of the contractor. Second, the first flight of the CEV was delayed until no later than 2014.

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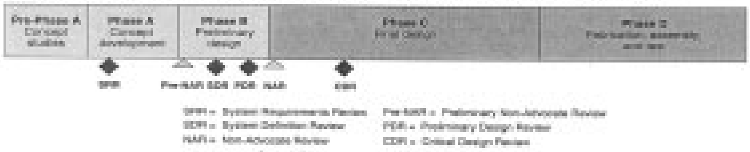
[1] NASA's cost estimate through 2011—$31 billion—included the costs of the R&T and RLEP projects needed to support the architecture. Its estimate for the first lunar landing—$104 billion—did not include $18 billion in funding for R&T and RLEP projects. To ensure consistency, the estimates for 2018 and 2025 are presented with R&T and RLEP funding included. The estimates include $20 billion to service the ISS.

NASA's Life Cycle for Flight Systems and Ground Support Projects through Phase D


Pre-Phase A
Concept studies
Phase A
Concept development
Phase B
Preliminary design
Phase C
Final Design
Phase D
Fabrication, assembly and test
SRR
Pre-NAR
SDR
PDR
NAR
CDR
SRR = System Requirements Review
SDR = System Definition Review
NAR = Non-Advocate Review
Pre-NAR = Preliminary Non-Advocate Review
PDR = Preliminary Design Review
CDR = Critical Design Review

Source: NASA.

Cost Estimating

Cost Estimate Issues

Historically, NASA has shown that it lacks a clear understanding of how much its programs will cost and how long they will take to achieve their objectives. NASA's cost estimates have often been unreasonable when committing to programs because of several factors, including inadequate requirements definition; changes in program content; and inadequate processes to establish priorities, quantify risks, and make informed investment decisions. GAO has reported on these issues for several years in both its high-risk series and in specific reviews of programs where NASA failed to apply discipline to its cost estimates to ensure those estimates were reasonable. For example, in 2002, GAO reported that since 1995, estimates for completion of the ISS had increased by $13 billion and the scheduled completion date had slipped 4 years. Also, in 2004, GAO conducted a review of 27 other NASA programs and reported that the initial baseline estimates for over half of those programs were understated.

Costs for NASA programs have historically been greater, on average, than initial estimates anticipated. A 2004 Congressional Budget Office (CBO) examination of 72 NASA programs spanning the past 30 years found that costs of NASA programs have increased, on average, 45 percent from initial budget estimates.

Firm Cost Estimates Cannot Be Developed at This Time, cont'd

Subsequent to the submission of NASA's fiscal year 2007 budget, the Constellation program conducted an internal bottom-up review (BUR) of program costs. The goal of the BUR was to identify the funding it would take to "get the job done," which, according to the BUR guidance, means conducting the first flight of the CEV to the ISS by 2012 and first lunar mission by 2017. This review attempted to determine the cost impact of several major changes that were made to the architecture. These changes included a reduction in CEV diameter from 5.5 to 5 meters, use of a five-segment RSRB and a Saturn-derived J-2x engine on the upper stage of the CLV, deletion of the unpressurized cargo CEV, the addition of an ISS docking system (Androgynous Peripheral Attachment System), and the inclusion of a Ka Band for High Definition Television on the CEV. Some of these architecture changes may help lessen technology development risks in the future program due to the planned commonality between the CLV and CaLV launch systems. While the results of this review were an attempt to provide more fidelity to the Constellation program's cost estimates, given the continued lack of a firm program baseline for requirements, design, and schedule, along with a continued lack of input from contractors, it is unlikely that the program had the level of detail available to support a true estimate of total costs this early in the program life cycle.

ESMD is conducting a follow-on review to the Constellation program's BUR as NASA enters its fiscal year 2008 budget formulation cycle. As part of this latest review, NASA has continued to evaluate changes to the program architecture and schedule, such as the use of the RS-68 engine on the CaLV and the delay of the first lunar mission to either fiscal year 2019 or fiscal year 2020.

The continued evolution of the exploration architecture serves to highlight the preliminary nature of architecture itself and its associated cost estimates. Although NASA is continuing to refine its cost estimates for implementing the architecture to provide a more reliable estimate of cost, history suggests that program costs could increase significantly over estimates. In 2004, CBO reported that fulfilling the Vision could require the addition of billions of dollars to NASA's estimates of cost or extending the schedule for the first lunar landing by several years. Applying NASA's average cost growth figure of 45 percent to the ESAS cost estimates, assuming NASA business as usual, would result in an increase of almost $14 billion over the $31 billion it estimates it will need through 2011. With a significant increase in NASA budgets unlikely, given the current national fiscal imbalance, this level of cost growth could result in an unsustainable long-term exploration program.

Funding Shortfalls

NASA Funding Approach

The NASA Administrator recently testified that the agency is facing challenges to ensuring adequate funding for the priorities of the President and Congress within available budgetary resources. He stated that NASA has adopted a "go as you can afford to pay" approach to funding its exploration missions. This approach assumes NASA's top line budget will grow at the moderate rate identified in the President's fiscal year 2007 budget request.

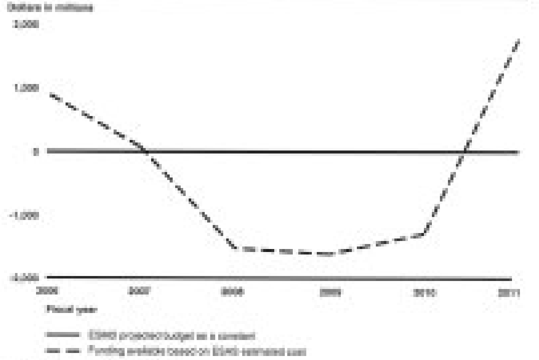
Under this approach, NASA would implement its priority missions within available resources and planned budgets through the redirection of funding for longer-term and lower-priority R&T elements within ESMD. As a result, several ESMD R&T programs and missions were discontinued, descoped, or deferred. That funding, in turn, was shifted into the Constellation Program to accelerate development of the CEV and the CLV.

Expected Budget Challenges Architecture Implementation

NASA will be challenged to implement the exploration architecture, given the agency's expected budget profile. The ESAS effort defined the recommended architecture and preliminary costs, which NASA contends would allow the program to be accomplished within available budgets through fiscal year 2011. However, phasing issues still needed to be resolved. On an annual basis, NASA cannot afford to implement the architecture, although, cumulatively, for fiscal years 2007-2011, the agency says it has the money available. Beginning with fiscal year 2014 and for the remainder of the decade, where the anticipated available budgets were adjusted for inflation, the ESAS cost projections show yearly multibillion-dollar shortfalls with an overall deficit through 2025 of over $18 billion.

The projected ESMD available budget figures used in the ESAS were developed well in advance of NASA's fiscal year 2007 President's budget submission. However, using the updated budget estimates from the fiscal year 2007 budget, the phasing issue becomes more pronounced when compared to ESAS estimated costs. As shown in the chart below, ESAS estimates could be accommodated within the ESMD available budget through fiscal year 2007. From fiscal year 2008 through fiscal year 2010, however, NASA anticipates annual budget shortfalls for implementing the architecture within ESMD to exceed $1 billion per year. This shortfall could be partially offset, at least within the Constellation program, by a carryover of approximately $1 billion in both fiscal years 2006 and 2007 as a result of funds redirected from R&T activities within ESMD to that program. In addition, NASA officials stated the Constellation program has requested more funding than required for its projects in several years to cover shortfalls in later years. For example, the Exploration Communication and Navigation Systems project within the Constellation program plans to roll over $56.2 million from the fiscal year 2007 budget to make up for budget shortfalls in fiscal years 2008, 2009, and 2010.

ESAS Estimated Cost versus ESMD Projected Budget by Fiscal Year



Source: NASA (data) and GAO analysis.

Funding Shortfall

Gap in Human Spaceflight

The Vision called for retirement of the space shuttle fleet by the end of this decade and that the CEV should be available no later than 2014, creating a potential gap in human spaceflight of up to 4 years. The NASA Administrator has stated that it is a priority of the agency to close this gap and that the agency has taken steps to have the CEV in service as close to 2010 as possible.

On the basis of lessons learned from the period between the end of the Apollo Program and the first flight of the space shuttle, the Administrator outlined several reasons why the CEV should not be delayed. These reasons include the potential for

- stagnation in the aerospace industry,
- loss of critical expertise,
- withering of the industrial base,
- higher overall program costs,
- program schedule delays, and
- loss of leadership in space exploration.

Congress has also voiced its concern over the potential gap in human spaceflight. In the National Aeronautics and Space Administration Authorization Act of 2005, Congress stated it is the policy of the United States to have the capability for human access to space on a continuous basis.

Expected Budget Challenges Architecture Implementation, cont'd

NASA's approach, however, appears to be contrary the agency's stated "go as you can afford to pay" approach to implement priority missions within available resources. In addition, the surplus shown in fiscal year 2011 is dependent upon dollars becoming available from the retirement of the space shuttle fleet, even though NASA officials stated the costs associated with retiring the space shuttle and transitioning to new architecture are not fully understood and the expected surplus could be less than anticipated. The shortfall presented by the fiscal year 2007 budget would not allow NASA to accomplish the stated program objectives within available resources over the next 5 years.

In addition, changes to the architecture implementation schedule have not been consistent within the Constellation program. As previously stated, NASA moved the scheduled initial operational capability (IOC) date of the CEV to no later than 2014 during the fiscal year 2007 budget formulation process. This change, along with modifications to the architecture, allowed NASA's estimates to meet its overall budget profile, despite continued year-to-year budget phasing issues. However, because of NASA's focus on minimizing the gap between the retirement of the space shuttle and the first flight of the CEV to the ISS, the program continued to attempt to meet the earlier IOC date for the CEV through its various analysis cycles. The earlier 2012 IOC date was retained as the planning date during the bottom-up review process, the Phase II request for proposal to the contractors involved CEV development, and the recent announcement concerning its intention to purchase the J-2x engine for the CLV from Pratt & Whitney Rocketdyne.

The 2012 date for CEV IOC, in addition to changes the Constellation program made to the architecture during the BUR process, did not alleviate issues with the short-term funding profile. According to Constellation program officials, the net result of these changes will add more cost to the early years of the program, when funding is already constrained and phasing issues persist. Although the results of the BUR will not be released, indications from Constellation program officials are that the estimated costs of the program are higher than the ESAS estimated costs and available funding per NASA's budget profile.

In the meantime, NASA continues to look for ways to resolve its budget phasing issues, such as by making additional changes to the exploration architecture. As the Constellation program executes its budget formulation process for the fiscal year 2008 budget cycle, it is currently analyzing options to the current architecture in an attempt to reduce development and production costs. For example, NASA recently announced that it intends to use five RS-68 engines instead of five SSMEs for the CaLV core stage, which would also require the CaLV core stage diameter to be increased to approximately 33 feet to accommodate the additional propellant needed by the RS-68 engines.

CEV Project

Best Practices

GAO has frequently reported on the importance of developing a sound business case before committing resources to a new product development effort. The business case in its simplest form is demonstrated evidence that (1) the need for the product is valid and that it can best be met with the chosen concept, and (2) the chosen concept can be developed and produced using existing and reasonably expected resources.

GAO has undertaken a best practices body of work on how leading developers use a knowledge-based approach to develop products that reduces risks and increases the likelihood of successful outcomes. This type of approach is based on the premise of attaining knowledge about a program and the resources available before making a contractual or financial commitment. Knowledge that supports a sound business case includes well-defined requirements, a preliminary design, mature technology, and realistic cost estimates.

Use of this approach has enabled leading organizations to deliver high-quality products on time and within budget. Conversely, GAO has also reported that major systems that have not established a sound business case have been plagued by cost overruns, schedule delays, decreased capability, and overall poor performance. NASA's track record in developing systems has not been good. GAO and others have reported that NASA has had numerous problems with its programs and projects, including underestimating program complexity and technology maturity, and inadequate review and systems engineering processes.

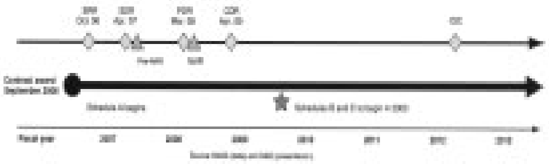
Lack of Sound Business Case Puts CEV Acquisition at Risk

NASA's acquisition strategy for the CEV places the project at risk of cost overruns, schedule delays, and performance shortfalls because it commits the government to a long-term product development effort before establishing a sound business case. In September 2006, NASA plans to award a contract for design, development, production, and sustainment of the CEV—before it has developed well-defined requirements, a preliminary design, mature technology, and firm cost estimates for the project. The CEV project might not have all the elements of a sound business case in place until the project-level PDR in March 2008. At the completion of the PDR, NASA will approve the selected prime contractor's preliminary design based on detailed, validated requirements. Further, CEV project officials indicated that the CEV project plans to retire all technology risks by the PDR. At that point, NASA will likely have the increased knowledge necessary to develop a sound business case that includes high-fidelity, engineering-based estimates of life cycle cost for the CEV project. With this business case in hand, NASA would be in a better position to commit the government to a long-term design and development effort. NASA officials disagree and have stated that it is appropriate for them to proceed with the contract award because the agency is selecting "a designer, not a design" for the CEV. In reality, by awarding a contract as planned in September 2006, NASA is not only committing to an unknown design but to production and long-term sustainment of the CEV as well.

The CEV contract scheduled for award in September 2006 will have three schedules. At the time of contract award, NASA will be responsible for fee earned and the reasonable, allowable, and allocable costs incurred by the contractor in the performance of Schedule A and the minimum quantities under Schedules B and C.

- **Schedule A** is for design, development, test and evaluation of the CEV. Deliverables under Schedule A include all test articles and two operational CEV vehicles—one human-rated variant and one pressurized cargo variant.
- **Schedule B** is for production beyond the two operational vehicles delivered under Schedule A. The CEV request for proposal states that the "guaranteed minimum" quantity for Schedule B is "two CEV," the type of which, according to NASA officials, is undetermined.
- **Schedule C** is for sustainment in support of operations and in support of Schedule B activities.

CEV Timeline



Source: NASA data and GAO presentation.

Note: Contract award for all schedules is planned for September 2006. Schedule B and C performance periods are from 2009 to 2014 with an additional 5-year performance option to end in 2019.

CEV Project

Past Development Attempts

NASA has tried unsuccessfully to develop a number of vehicles to replace the shuttle over the past three decades. In the 1980s NASA initiated the National Aero-Space Plane (NASP) to build and test a manned experimental flight vehicle for demonstrating single-stage-to-orbit space launch and sustained hypersonic cruise capability. NASA canceled the program as it was experiencing cost overruns, schedule delays, and technology problems. GAO reported that from 1986 to 1993 NASA spent $398 million for the NASP program.

In the 1990s, NASA began the X-33 program to develop single-stage-to-orbit technology and the X-34 to demonstrate reusable two-stage-to-orbit technologies. According to a 2006 Congressional Research Service report, NASA terminated the X-33 and X-34 in March 2001—after spending over $1.4 billion—because the cost to complete them was too high relative to the benefits. In 1999, GAO reported that technical problems and unrealistic cost estimates on the X-33 project alone led to cost overruns of $75 million and over a year's delay.

In 2004, after the announcement of the Vision, NASA canceled the Space Launch Initiative (SLI) program, which was to provide both launch capabilities and an emergency crew return from the ISS. NASA's Inspector General reported that NASA did not verify and validate basic requirements for its second generation space transportation, while GAO reported that key management controls could not be implemented until such requirements were defined. GAO estimates that from 2001 to 2005 NASA provided the SLI program with about $5 billion in funding.

Lack of Sound Business Case Puts CEV Acquisition at Risk, cont'd

An important step in developing a sound business case is defining requirements. The acquisition strategy for the CEV lays out a series of reviews to validate and approve CEV requirements. These reviews result in approved system-level requirements at the October 2006 System Requirements Review (SRR), and approved subsystem-level requirements at the April 2007 System Definition Review (SDR) and culminate with validated and approved component-level requirements at the March 2008 PDR. Under the current CEV strategy, NASA will select the winning contractor about 1 month before the system level requirements are approved at the SRR, over a year and a half before detailed component-level requirements are approved at the PDR.

Another aspect of a sound business case is having mature technologies before committing to product development. The CEV's acquisition strategy is predicated upon using mature technologies as the basis for system development. However, contractors will also be given discretion to include immature technologies in areas where technology advancement is critical to meeting requirements. NASA has independently identified technology risks and implemented advanced technology development projects to address risks in the areas of the thermal shielding needed for reentry and the landing systems needed for ground landings. CEV project officials also expect that each contractor's proposal will include additional technology development risks. Under the current CEV strategy, NASA is awarding a contract for product development and production of the first two variants of the CEV before it has resolved these technology development risks.

Appendix

Contributors

If you have any questions concerning this briefing, please call Allen Li at (202) 512-4841. Other key contributors to this briefing were James L. Morrison, Assistant Director; Rick Cederholm; Shelby S. Oakley; Guisseli Reyes; Sylvia Schatz; and John S. Warren, Jr.

Scope and Methodology

To assess the extent to which NASA has identified the architecture and costs necessary to implement the *Vision* and whether NASA's exploration architecture fits within the agency's projected available budgets, we reviewed and analyzed NASA's Exploration Systems Architecture Study, fiscal year 2007 budget request, ground rules and assumptions provided from the Constellation program to project-level management estimators to perform the BUR, guidance for use in preparing the fiscal year 2008 budget request, NASA cost-estimating guidance in the NASA *Cost Estimating Handbook*, and congressional hearings and testimonies pertaining to NASA and the *Vision*. We also conducted interviews with NASA headquarters officials from the Cost Analysis Division, the Exploration Systems Mission Directorate, and the Constellation Program; Constellation program and CEV project officials at Johnson Space Center; CLV project officials at Marshall Space Flight Center; and cost analysts from Kennedy Space Center. During these interviews, we discussed the methodologies used in preparing the ESAS and subsequent cost estimates, architecture changes after ESAS and the trades being considered, budgeting issues, and procurement strategies and activities.

To assess the risks associated with NASA's acquisition strategy for the CEV project, we reviewed and analyzed CEV project documentation, including draft project plans, draft requirements documents, technology development plans, documentation included in the contract request for proposals, and documentation for past NASA human space flight acquisition programs. We compared NASA's plans for the CEV with criteria contained in GAO best practices work on systems acquisition. We also conducted interviews with NASA headquarters officials from the Exploration Systems Mission Directorate, Constellation Program and CEV project officials at Johnson Space Center, and CLV project officials at Marshall Space Flight Center.

Chairman BOEHLERT. The hearing will come to order. I want to welcome everyone to today's important hearing: the Committee's first public discussion of the Crew Exploration Vehicle, or Orion, project since we had the Administrator before us in March, and the first review in Congress since Lockheed Martin was awarded the contract for Orion at the end of August.

Let me start by reiterating my support for the President's *Vision for Space Exploration,* which I think is an important national undertaking. Let me also reiterate my determination that NASA not become a single-mission agency. Human space flight can't succeed at the expense of Earth science, space science, and aeronautics.

So NASA has to move ahead with Orion deliberately, but also cautiously, and Congress has to keep a keen and constant eye on the project. Neither the Agency nor the Nation can afford another space station, a project that for all its technical magnificence has seen its costs balloon while its capabilities shrank to near the vanishing point.

This may very well be the last hearing on NASA. Some people will breathe a sigh of relief. But I hope we will have set a pattern of friendly, but rigorous vigilance that will be continued as the Nation moves ahead with work on returning to the Moon.

I am pleased to say that NASA itself also seems to be operating at a high level of vigilance. The agency is trying to base Orion on technologies that have already been used successfully in other programs; and I am also very glad to see that NASA modified the Lockheed Martin contract for Orion as a result of the General Accountability Office study this committee requested. That is a great example of how sensible oversight can work to the advantage of the Agency being reviewed, and frankly, it is a credit to this committee, to GAO, and to NASA that the contract was modified.

But that hardly closes the issue before us. GAO correctly points out that NASA does not yet have a final design or cost estimate for Orion. That is not a criticism of NASA, that is just where we are in the process, and Congress has to recognize how fluid the situation is, although far less fluid than it was at this time last year.

GAO believes that NASA should not have let as an extensive contract as it did, given the uncertainties, and they make a plausible case. NASA has made reasonable arguments in response, and the contract has been let so we don't have to rehash that issue here. What we do have to do is learn what should Congress be doing, and what information should it be seeking to exercise strict oversight as the project moves forward. And what additional steps should NASA take to make sure that project costs do not escalate?

I look forward to getting answers to those questions. We have the right folks before us to get those answers, and I want to welcome Dr. Scott Horowitz from NASA for his first public appearance before the Committee. I think you will see, after you hear and are exposed more to Dr. Horowitz, he is a congenial, knowledgeable guy, and it is a pleasure to work with him. He meets with staff all the time, and that is a productive time use, and hopefully, we won't be as hard on him today as they are.

With that, let me turn to my co-partner here, Mr. Gordon of Tennessee.

[The prepared statement of Chairman Boehlert follows:]

PREPARED STATEMENT OF CHAIRMAN SHERWOOD L. BOEHLERT

I want to welcome everyone to today's important hearing, this committee's first public discussion of the Crew Exploration Vehicle, or Orion, project since we had the Administrator before us in March, and the first review in Congress since Lockheed Martin was awarded the contract for Orion at the end of August.

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I look forward to getting answers to those key questions. We have the right folks before us to get those answers, and I want to welcome Dr. Scott (Doc) Horowitz from NASA for his first public appearance before the Committee. He meets with the staff all the time, and hopefully we won't be as hard on him today as they are.

Mr. Gordon.

Mr. GORDON. Thank you, Mr. Chairman.

I once tried out for my church choir, and I was quickly told that I had such a bad voice that I was not even able to make a joyful Lord—noise to the Lord, so my birthday present to you today is not to sing. Unfortunately, I can't say that for Dana Rohrabacher. I am not sure what he will do, but we do wish you a happy birthday, and we welcome our witnesses today.

First, let me make clear what this hearing is not. It is not a hearing about whether or not the Nation should build a Crew Exploration Vehicle. It is not a hearing about whether or not the right contractor team won the CEV contract. And it is not a hearing about whether or not the U.S. should return to the Moon. Instead, this hearing is an examination of whether or not NASA is pursuing the right acquisition strategy for the CEV, whether it has adequately planned for the challenges inherent in the program, and whether it has budgeted sufficient funds to complete the CEV. The last question is particularly important because if there is cost growth in the CEV program, it has the potential to do serious damage to NASA's other programs, as well as other parts of the exploration initiative.

I don't want to see that happen. I want to see the CEV program succeed, and that is why I was very concerned when the GAO reported to Chairman Boehlert and I in late July that, and I quote "NASA's current acquisition strategy for the CEV places the project at risk of significant cost overruns, schedule delays, and performance shortfalls."

Equally troubling were GAO's findings on the issues of whether NASA's overall exploration architectural costs estimates fit within the Agency's projected available budget. Once again, to quote GAO, "There are years when NASA does not have sufficient funding to—funds to implement the architecture. Some yearly shortfalls exceed $1 billion, while in other years the funding available exceeds needed resources." And "NASA's preliminary projections—projects multi-billion dollar shortfalls for the Exploration System Mission Directorate in all fiscal years 2014 through 2020." In other words, we may be seeing another example of lofty goals being set without those proposals—without those proposing them identifying where resources needed to achieve these goals will be coming from in future years.

I want to note, of course, that NASA non-concurred with GAO's findings and believes that it has a good plan for both the CEV acquisition and the overall exploration program. I would caution, however, that those are words we have heard before. I would remind my colleagues that some 18 months ago, NASA testified before this committee about its plans for acquiring a CEV, indicating that it had a well thought out approach to the CEV program.

Let me offer a quote from NASA's February 16, 2005, testimony. "The CEV will be developed in a spiral approach wherein early demonstrations and prototypes are used to demonstrate capabilities, validate technologies, and mitigate risk, all along an evolutionary path toward a mature design. The first spiral development plan will provide the capacity to deliver humans to orbit in a CEV by the year 2014."

Now, as you recall, last year's approach was going to maintain a competition between two contractor teams until 2008 when there would a competitive "fly-off" prior to the award of the CEV development contract. NASA also assured Congress last year that CEV and the CLV acquisition plan would be within budget that would meet the 2014 timeframe.

It is now 2006. NASA has eliminated the spiral development approach, has decided not to maintain the competitive fly-off, and has added almost $7 billion to the CEV and CLV program relative to what last year's five-year funding plan said would be needed. And after all of that, NASA is indicating that CEV still will not enter operational service until 2014, due to budgetary constraints.

My intent in reciting this history is not to embarrass NASA; it is simply to make the point that we have received assurances from this agency in the past that everything is under control, and we have had other painful reminders in recent months of large-scale acquisition programs in other agencies under our jurisdiction going off course. We cannot afford to have that happen again.

Today's hearing will provide an opportunity for the Committee to hear from both GAO and NASA on these issues. And once again, as my friend Chairman Boehlert has pointed out, our concern here is that if things get out of kilter even with the best intentions, it is going to result in potentially cannibalizing other programs within NASA, which makes us lose support within Congress for NASA, which then can lead to appropriations battles where they could take some of this out of our hands. That is not where we want to be. We want to work with you as good partners to try to alleviate that, because we are all going to suffer if that is not the case.

And again, I welcome you here.

[The prepared statement of Mr. Gordon follows:]

PREPARED STATEMENT OF REPRESENTATIVE BART GORDON

Good afternoon. I'd like to join the Chairman in welcoming the witnesses to today's hearing.

First, let me be clear about what this hearing is *not.* It is not a hearing about whether or not the Nation should build a Crew Exploration Vehicle. It is not a hearing about whether or not the right contractor team won the CEV contract. And it is not a hearing about whether or not the U.S. should return to the Moon.

Instead, this hearing is to examine whether or not NASA is pursuing the right acquisition strategy for the CEV, whether it has adequately planned for the challenges inherent in the program, and whether it has budgeted sufficient funds to complete the CEV.

The last question is particularly important, because if there is cost growth in the CEV program, it has the potential to do serious damage to NASA's other programs as well as to other parts of the exploration initiative.

I don't want to see that happen. I want to see the CEV program succeed. That is why I was very concerned when the GAO reported to Chairman Boehlert and me in late July that: *"NASA's current acquisition strategy for the CEV places the project at risk of significant cost overruns, schedule delays, and performance shortfalls. . ."*

Equally troubling were GAO's findings on the issue of whether NASA's overall exploration architecture cost estimates fit within the Agency's projected available budgets. To again quote GAO: *". . .there are years when NASA does not have sufficient funding to implement the architecture. Some yearly shortfalls exceed $1 billion, while in other years the funding available exceeds needed resources. . ."*

And, *"NASA preliminarily projects multi-billion-dollar shortfalls for [NASA's] Exploration System Mission Directorate in all fiscal years from 2014 to 2020."*

In other words, we may be seeing another example of lofty goals being set without those proposing them identifying where the resources needed to achieve those goals will be coming from in future years.

I want to note, of course, that NASA "non-concurred" with the GAO's findings and believes that it has a good plan for both the CEV acquisition and the overall exploration program. I would caution, however, that those are words we have heard before.

I would remind my colleagues that some 18 months ago, NASA testified before this committee about its plans for acquiring the CEV, indicating that it had a well-thought-out approach to the CEV program.

Let me offer a quote from NASA's February 16, 2005 testimony: *"[The CEV] will be developed in a 'spiral' approach, wherein early demonstrations and prototypes are used to demonstrate capabilities, validate technologies, and mitigate risk, all along an evolutionary path toward a mature design. The first spiral development planned will provide the capability to deliver humans to orbit in a CEV by 2014."*

As you will recall, last year's approach was going to maintain a competition between two contractor teams until 2008 when there would be a competitive "fly-off" prior to award of the CEV development contract.

NASA also assured the Congress last year that its CEV and CLV acquisition plan came with a budget that would meet its 2014 timetable.

It's now 2006. NASA has eliminated the spiral development approach, has decided not to maintain the competitive fly-off, and has added almost **$7 billion** to the CEV and CLV program relative to what last year's five-year funding plan said would be needed. And after all of that, NASA is indicating that the CEV still will not enter operational service until 2014 due to budgetary constraints.

My intent in reciting this history is not to embarrass NASA—it is simply to make the point that we have received assurances from this agency in the past that "everything is under control" and we have had other painful reminders in recent months of large-scale acquisition programs in other agencies under our jurisdiction going off course. We cannot afford to have that happen again.

Today's hearing will provide an opportunity for the Committee to hear from both GAO and NASA on these issues. I look forward to their testimony

Chairman BOEHLERT. Thank you very much, Mr. Gordon.

Now, for the distinguished Chairman of the Subcommittee, Mr. Calvert.

Mr. CALVERT. I thank the gentleman, and I, too, want to share with my colleague on the other side, bid you birthday wishes. Happy birthday. Happy 70th birthday. My goodness, that is great. I want to say from the bottom of my heart, surely——

Chairman BOEHLERT. I should note parenthetically that Mr. Gordon, on the side, said, "I wasn't going to mention that."

Mr. CALVERT. Hey, we all want to make it. I don't know if I will ever make it. But it has been a great six years with you here as Chairman. This institution will be less of a place when you retire. I think that you have done a fantastic job here. It has really been a pleasure serving with you, and I want you to know that.

NASA, as you know, has undertaken the first steps of an exploration program that will continue over the next several decades. It will inspire the next generation of scientists and engineers, just as Apollo inspired an earlier generation in the 1960s. Two major contracts recently awarded are moving us, I think, in the right direction. The Space Shuttle has completed its third flight since the *Columbia* disaster, and we are now on a path to complete the International Space Station. The Commercial Orbital Transportation Services Award recently had been awarded to Space X and Rocketplane Kistler. Both of these entrepreneurial companies are developing logistics systems to service the International Space Station, while on a parallel plane, the Lockheed Martin company will be developing a Crew Exploration Vehicle, or Orion, to explore the Moon, Mars, and beyond.

I want to applaud NASA for their timely schedule of procurement for this major undertaking. The two procurement announcement, or the first of several major procurement award announcements, were made in order to achieve the *Vision for Space Exploration*. I am certainly pleased that the Committee was the first to endorse the Vision when we unanimously passed the *NASA Authorization of 2005* last July. The Congress overwhelmingly passed the Authorization last year, and now NASA is carrying out the will of the Congress. Many of the overall decisions for the Vision have been made: a capsule approach for the Crew Vehicle to minimize a technical risk and maximize crew safety; a launch vehicle that builds on the Space Shuttle technology of upper stage engine derive that was used on Saturn V, and a main engine currently used on Delta IV.

It seems that all of these programs contribute to the knowledge-based approach that is laid out by the GAO. I believe NASA has a more advanced state of knowledge than the Agency has had for many of their earlier procurements. In addition, the NASA acquisition strategy for the Vision is more flexible and has built in incentives, options, and provisions for termination if necessary. The aim is to improve contractor performance.

I know how tight the development budgets will be for this program. I am concerned that some of these recommendations could impose delays, resulting in substantial cost increases. Congress will continue to exercise its oversight responsibility on this program, just as we are today. However, we cannot analyze the program to death. We must move forward, stabilize requirements, maintain a tight design and development schedule to minimize the gap between the Shuttle retirement and the operational Crew Exploration Vehicle, and bring Orion online within the allowed or allocated budget.

I know that NASA and these contractors have brought in the best minds to work on this program. We now have an exciting program for NASA to carry out, and for the next generation to aspire to to be a part. The decision has been made to move forward, and we need to let NASA and the United States lead the world in our exploration of space.

Thank you, Mr. Chairman.

[The prepared statement of Chairman Calvert follows:]

PREPARED STATEMENT OF CHAIRMAN KEN CALVERT

NASA is undertaking the first steps of an exploration program that will continue over several decades. It will inspire the next generation of scientists and engineers just as Apollo inspired an earlier generation in the '60s. Two major contracts recently awarded are moving us in the right direction. The Space Shuttle has completed its third flight since the *Columbia* disaster and we are now on the path to complete the International Space Station.

The Commercial Orbital Transportation Services awards recently have been awarded to SpaceX and to Rocketplane/Kistler. Both entrepreneurial companies are developing a logistics system to service the International Space Station, while on a parallel plane, the Lockheed Martin Company will be developing the Crew Exploration Vehicle, or Orion, to explore the Moon, Mars and beyond.

I applaud NASA for their timely schedule of procurement for this major undertaking. The two procurement announcements are the first of several major procurement award announcements that will be made in order to achieve the *Vision for Space Exploration.* I am pleased the Committee was the first to endorse the Vision when we unanimously passed the *NASA Authorization of 2005* last July. The Congress overwhelmingly passed the Authorization late last year and now NASA is carrying out the will of the Congress.

Many of the overall decisions for the Vision have been made—a capsule approach for the crew vehicle to minimize technical risk and to maximize crew safety; a launch vehicle that builds on the Space Shuttle technology; an upper stage engine derived from that used on the Saturn V; and a main engine currently used on the Delta IV. It seems that all of these programs contribute to a "knowledge-based" approach, as laid out by the GAO. I believe NASA has a more advanced state of knowledge than the Agency has had for many of their earlier procurements. In addition, the NASA acquisition strategy for the Vision is more flexible and has built in incentives, options, and provisions for termination if necessary. The aim is to improve contractor performance.

I know how tight the development budgets will be for this program and am concerned that some of these recommendations could impose delays resulting in substantial cost increases. Congress will continue to exercise its oversight responsibilities on this program, just as we are today. However, we cannot analyze the program to death. We must move forward and stabilize the requirements; maintain a tight design and development schedule to minimize the gap between the Shuttle retirement and an operational Crew Exploration Vehicle; and bring Orion online within the allocated budget.

I know that NASA and its contractors have brought in their best minds to work on this program. We now have an exciting program for NASA to carry out and for our next generation to aspire to be a part of. The decision has been made to move forward and we need to let NASA and the United States lead the world in our exploration of space.

Chairman BOEHLERT. Thank you very much, Chairman Calvert. Mr. Udall.

Mr. UDALL. Thank you, Mr. Chairman. In the spirit of Mr. Gordon and Mr. Calvert's remarks, I would also like to make a brief comment about your tenure and your friendship and your leadership. It has been said that a statesman is a dead politician, and somebody said that, yeah, we need more statesmen. I think you are in a quasi-statesman category today, and soon after you leave the House, you will be known as a full statesman for the way you conducted yourself, the leadership particularly on this committee. I am particularly indebted to you for your hard work on behalf of energy independence, doing something about climate change, I think looms as one of the biggest challenges facing not only our country, but the world, and you will be sorely missed.

I, too, want to welcome all—the two witnesses today here. We have got a lot to cover so I will be very brief.

I want to mention that I am encouraged that the recent CEV contract was by all accounts the result of a hard-fought competition between the two high-quality contractor teams, and I did want to congratulate Lockheed Martin, which coincidentally is based in my home State of Colorado, on winning that competition.

I would also like to echo the comments made by Ranking Member Gordon, and I am, of course, troubled by the issues raised by the GAO in their July 17 report. I look forward to hearing both from the GAO and NASA today.

Given the importance of the CEV program to the future of the Nation's human space flight activities, I think it is imperative that this committee engage in sustained, serious oversight of it, as well as the other parts of NASA's exploration initiative to ensure that they are carried out in an efficient and responsible manner. I say this not because I have any concerns about the dedication and commitment of NASA and the contractor team to the success of the program; rather, it is because from my vantage point on the Armed Services Committee, I have seen that dedication and commitment are by themselves are not sufficient to keep major systems acquisitions from sometimes running into trouble. We all know examples of important programs that have gotten off track and suffered significant cost growth and schedule delays.

As the GAO has pointed out other occasions "Good intentions aren't enough." There also needs to be a clear understanding of requirements, credible costs, and scheduled estimates and a disciplined approach to program management. All of us want NASA's CEV program to succeed, and in that spirit, I believe that today's hearing can provide a forum for a constructive review of NASA's plans.

And again, I look forward to hearing from our two esteemed witnesses. Thank you, Mr. Chairman.

[The prepared statement of Mr. Udall follows:]

PREPARED STATEMENT OF REPRESENTATIVE MARK UDALL

Good afternoon. I'd like to join my colleagues in welcoming our witnesses to today's hearing. We have a lot of issues to cover today, so I will just make a few observations.

First, I am encouraged that the recent CEV contract award was by all accounts the result of a hard-fought competition between two high-quality contractor teams.

And I want to take this opportunity to congratulate the Lockheed Martin team—which coincidentally is based in my home State of Colorado—on winning that competition.

Second, I want to echo the comments made by Ranking Member Gordon. I am, of course, troubled by the issues raised by the GAO in their July 17th report, and I look forward to hearing from both GAO and NASA today about what has been done to address those issues.

Given the importance of the CEV program to the future of the Nation's human space flight activities, I think it's imperative that this committee engage in sustained, serious oversight of it, as well as the other parts of NASA's exploration initiative, to ensure that they are carried out in an efficient and responsible manner.

I say this not because I have any concerns about the dedication and commitment of NASA and the contractor team to the success of the exploration program.

Rather, it's because from my vantage point on the Armed Services Committee, I have seen that dedication and commitment are by themselves not sufficient to keep major systems acquisitions from sometimes running into trouble.

We all know of examples of important programs that have gotten off track and suffered significant cost growth and schedule delays.

As the GAO has pointed out on other occasions, "good intentions" aren't enough. . .

There also needs to be a clear understanding of requirements, credible cost and schedule estimates, and a disciplined approach to program management.

We all want NASA's CEV program to succeed. I hope that today's hearing can provide a forum for a constructive review of NASA's plans, and I look forward to hearing from our witnesses.

Chairman BOEHLERT. Thank you very much.

The Chair, as a point of personal request, recognizes Mr. Rohrabacher.

Mr. ROHRABACHER. Before you get away, I want to thank you for all the great times we have had here and the intellectual, I might say, stimulation that we have had on so many—exploring so many areas that they themselves are interesting, but it is also interesting how different approaches can be an exciting way to actually look at our potential. So happy birthday to the Chairman. Also, I want to note that in the future, and as you move on and you are not here, every time I start talking about global warming I will look in front of me and I will see your skeptical face there on that painting and it will remind me of some of these great discussions that we have had.

Finally, on our issue for today, let me just say that we have behind us—your face is in front of us, but behind us we still have this slogan that says "Where there is no vision, the people will perish." There is an actual—that is not the end of the quote, interestingly enough. The other part of the quote goes "Where there is no prioritization, there is only failure." I would hope people know that you can fail by not trying to do enough, but most of the time we fail—and my experience is that we have failed because we have tried to do everything for everybody. And the President laid down a plan, a game plan, a priority of this—of a lunar approach first, a lunar goal, and I think we—that we now have in front of us the first manifestation of that prioritization of goals, and I am very pleased that the Administration is doing this in a cost effective way by trying to use older technology, meaning technology that is already proven, and putting it together in new sources of rockets, et cetera.

And with that said, thank you, Mr. Chairman, for all of your leadership. We will miss you and I will miss some of our back and forths.

Chairman BOEHLERT. Can I tell them about the secret gift you gave me? He gave me a birthday card and said, "You know, I think maybe we ought to look at global warming." It is for real, but thank you very much. I thank all my colleagues. You have been very kind and it is a pleasure to work with all of you.

I would remind one and all we have another hearing tomorrow, so polish up your rhetoric. We will have another opportunity.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good afternoon. I want to thank the witnesses for appearing before the Committee to examine National Aeronautics and Space Administration's (NASA) development strategy for the Crew Exploration Vehicle (CEV) in light of the recent report issued by the Government Accountability Office (GAO) expressing concerns over NASA's ability to budget for the CEV program.

In January 2004, President Bush announced his *Vision for Space Exploration* (VSE) which include key human space flight milestones, such as retirement of the Space Shuttle in 2010, completion of the International Space Station (ISS), and development of a new CEV, known as Orion. According to NASA, Orion will help further our understanding of Earth, the solar system, the universe, and the origins of life itself.

On July 17, 2006 GAO issued a report expressing their serious concerns over NASA's acquisition of Orion. The report examines whether NASA's exploration initiative estimated costs fit within the Agency's projected available budgets and determined that NASA will be significantly challenged to meet their intended goal. The recommendations submitted by GAO suggest Congress should consider restricting annual appropriations and limit NASA's obligations for Orion to only the amount of funding necessary to support activities needed to successfully complete the project's preliminary design review. I look forward to hearing from Dr. Horowitz from NASA and Mr. Allen from GAO on the exploration program.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman and Ranking Member.

NASA is especially important to Texas. Space travel has sparked the minds of generations of Americans. In Texas, it has meant jobs and strong local economies.

I recently hosted an astronaut, Ms. Stephanie D. Wilson, at an event in Washington. Just watching footage from Ms. Wilson's time in a zero gravity environment was incredible and inspiring.

We understand that NASA has had a challenging task to plan out the short- and long-term details for the Orion project. It is in our interest as policy-makers and the interest of our constituents to stay engaged in the process.

As the Agency prepares to embark on a new journey with the Orion Crew Exploration Vehicle, this committee wants to do all it can to provide support so that the initiative succeeds.

Since this is the first time the Full Committee on Science has interacted officially with NASA since the last successful space launch, I extend warmest congratulations on its success.

It is my hope that this strong record of achievement speak for the public's confidence in future endeavors such as Orion.

Thank you, Mr. Chairman. I yield back the balance of my time.

Chairman BOEHLERT. Let us go to our two witnesses, and very distinguished witnesses they are.

Dr. Scott Horowitz, Associate Administrator, Exploration Systems Mission Directorate, National Aeronautics and Space Administration. Doctor, it is good to have you here. And Mr. Allen Li, Director, Acquisition and Sourcing Management for the highly regarded and respected General Accountability Office. Not only is the office highly regarded and respected, so too are you, sir. Thank you.

Dr. Horowitz, you are up.

STATEMENT OF DR. SCOTT J. HOROWITZ, ASSOCIATE ADMINISTRATOR, EXPLORATION SYSTEMS MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Dr. HOROWITZ. Thank you, sir.

Good afternoon, Chairman Boehlert, Ranking Member Gordon, and Members of the Committee. Thank you for inviting me here today to testify how we at NASA are taking the first step in turning the *Vision for Space Exploration* into reality with the Crew Exploration Vehicle called Orion.

First of all, sir, I would like to thank this committee, especially you, sir, for—and Member Gordon as well as Congressmen Calvert and Udall for your vision and your leadership that brought us the *NASA Authorization Act of 2005.* Chairman, I couldn't help but notice your new picture here on the wall, and I know it is a great honor, only second to if it was hanging in the Hall of Fame. I know that this Act is going to be an important part of your legacy.

For years, NASA struggled with a lack of clear guidance. Through your efforts, we now have a clear set goals and objectives to focus the great talents of our NASA team. This law provides clear guidance for Aeronautics, Science, Space Ops, and Exploration. For human space flight, we now have clear, concise direction: finish the International Space Station, retire the Space Shuttle, develop a Shuttle-derived transportation system that will be operational by 2014, and give us the capability to go back to the Moon by 2020. These are the first steps to creating a sustained human presence on the Moon in preparations for journeys to Mars and beyond.

Mr. Chairman, NASA engineers have done too much view graph engineering in the all too recent past. As a rocket scientist, astronaut, test pilot, and experimental aircraft builder, I can tell you there's nothing better than hands-on experience. Sir, it is time for NASA to put down the view graphs and get our hands dirty. It is time to start designing, building, and testing real flight hardware, and we are.

Let me share with you some of the accomplishments so far this year. We have successfully accomplished two Space Shuttle missions to the ISS and are finishing its assembly. We said at the beginning of the year that we would complete the competition for the Crew Exploration Vehicle, and also enter into funded Space Act Agreements to demonstrate commercial crew and cargo services for the ISS. On August 18, we signed two Space Act Agreements with Space X and Rocketplane Kistler to demonstrate the commercially operated transportation services. On August 31, we awarded a major contract to Lockheed Martin for the design and development of Orion. We are well on our way to developing the Ares I launch vehicle, with development of the first stage underway, and the J–2X second stage engine program off and running. We have constructed and conducted Orion body mass drop tests at Langley, thermal protection systems arc jet tests at Ames, wind tunnel tests and engine tests at Marshall. This week at Kennedy Space Center, we completed industry and global assessments on launch and operations to reduce future infrastructure and ops costs.

Some major milestones for you to keep your eyes open for in the future are in 2008. We will launch the lunar robotic orbiter being developed at Goddard, and it will have its secondary payload, Lunar CRater Observation and Sensing Satellite (LCROSS), being developed at Ames. We are 30 months away from the first launch of a full-scale test article of the Ares I, scheduled for early 2009.

Mr. Chairman, in your invitation letter, you asked me to specifically address two questions. One, how will NASA strategy reduce the total cost for production and operations of the Orion Crew Exploration Vehicle, and two, what actions have we taken to address concerns raised by the GAO?

First, the most important factor that will reduce the total cost for production in operations of Orion is its simplicity. The Ares I launch vehicle and Orion spacecraft are far simpler designs than the Space Shuttle, and thus will need few engineers and technicians to design, develop, test, and operate. There are no exotic technologies or evolutionary designs required to accomplish our mission.

We take the GAO concerns quite seriously, and have had our team meet with GAO, and Mr. Li and I have personally met. We are implementing our management approach dictated by NASA program guidance 7120.5, which incorporates the GAO recommendations on implementing a knowledge-based acquisition framework. Also, based on our discussions, we have made some modifications to our contract with Lockheed Martin, the most notable being the use of options which preserve NASA's flexibility in case of any unforeseen trouble. We have the knowledge and technical framework to move forward. The consolation program, our NASA Smart Buyer team, Lockheed Martin, and Northrop Grumman Boeing teams all completed initial designs based on our requirements. If you were to place a model of each of these designs on the table, except for the shape of the solar rays, you couldn't tell the difference. The largest change in a year we have made to the vehicle is we shrunk it from five and a half meters to five meters, about this much. That is the largest change we have made.

We know what we need to do; it is time to execute.

In closing, Mr. Chairman, I would like to share with you how important this challenge is to me personally, because it reflects how many of us at NASA feel. February 1, 2003, was the darkest day of my NASA career. When the Space Shuttle *Columbia* didn't come home, I lost seven friends. I spent the next several months in Eastern Texas helping with the recovery efforts, and in the back room of our control center, myself and several of my fellow astronauts wondered if the United States might stop exploring space altogether, and what would that mean to our nation's future.

It was there that the initial design concepts were born that would allow us to send astronauts to space with more reliability and safety. The risks are worth the rewards. Every person that has ever strapped themselves to the top of a rocket understands this. We need to learn from our past and not become complacent about the costs and risks involved in human space flight. Fortunately, our nation's leaders recognize this as well and understand the importance of worthy goals for our space program. Mr. Chairman, we have a lot of work ahead of us, and we have the team in place who remembers the lessons from that dark day and have dedicated themselves to this most noble of causes.

Again, thank you for your leadership and support of our nation's space program, and I look forward to your questions.

[The prepared statement of Dr. Horowitz follows:]

PREPARED STATEMENT OF SCOTT J. HOROWITZ

Mr. Chairman and Members of the Committee, thank you for the opportunity to appear before you today to outline NASA's progress in developing Orion, the Nation's next-generation piloted spacecraft.

In the *NASA Authorization Act of 2005* (P.L. 109–155), the Congress provided a national framework that supports and expands upon the Administration's *Vision for Space Exploration.* These policy pillars are helping to shape, align, and focus NASA's human exploration and robotic activities. With this foundation, NASA now has a broad, future-focused context for its low-Earth orbit activities. These include flying the Space Shuttle safely until its 2010 retirement and completing the International Space Station (ISS) in order to advance science, exploration, and international collaboration. NASA is also now taking the initial steps to extend humanity's presence across the solar system by moving beyond our beachhead in space on the ISS. We will return to the Moon by the end of the next decade to live and work on a sustained basis to meet a range of objectives, including the preparation for journeys to Mars and beyond.

A sustained presence on the Moon will advance U.S. preeminence, commerce and science, and prepare us for future expeditions outside Earth's immediate neighborhood. I am honored and humbled to represent such a noble, important, and far-reaching effort. It taps into a natural curiosity about space, stirs our imagination, and stimulates creativity and productivity. It is a program that will make a difference in our lives, on our planet, and to our children's children's future.

Time to Put the Viewgraphs Down and Get Going

In August of this year, NASA took a major step to maintain the Nation's leadership position in space when it awarded to Lockheed Martin Corporation a contract to design and develop the Crew Exploration Vehicle, now dubbed Orion. The contract took effect on September eighth. Named for one of the brightest and most recognizable star formations in the sky, Orion is the central member of a family of spacecraft and launchers that NASA's Constellation Program is developing for the next generation of explorers. Two industry teams, Lockheed Martin and a consortium of Northrop Grumman and Boeing, spent 13 months refining concepts, analyzing requirements, and refining the design for Orion.

Orion represents the culmination of literally decades of hardware heritage, design, and trades. We now have the opportunity to develop a system with greater safety, reliability, capability, and affordability than the Space Shuttle. The *Columbia* tragedy and the earlier *Challenger* tragedy clarified the need to address these issues and form a national context where our human space flight capabilities can be openly addressed. Thank you for providing a national framework in which to begin to implement our dreams and build upon the sacrifice of our colleagues. We already are working hard on this transition from our current capabilities into the capabilities of the future.

Astronauts will have a less risky ride to and from space aboard Orion. While all space flight involves risk, if we are to explore, we must reduce the risk of launching below the current level. This new crew module is inherently safer than the Shuttle because it will be placed on top of its booster. This will protect it from potentially deadly launch system debris during ascent, and allows the addition of an abort system that can separate capsule and crew from the booster in an emergency.

Orion is the next-generation piloted spacecraft. For missions to the Moon, Orion will carry up to four astronauts to low-Earth orbit and, once there, link up with a lunar surface access module for the trip to lunar orbit. The access module will descend to the Moon's surface for up to a week for sortie missions and up to six months for outpost missions, while Orion orbits, awaiting its return. The two vehicles will link up again at the end of the surface mission, and the astronauts will ride back to Earth in Orion. The capsule will re-enter the atmosphere and descend on parachutes back to Earth. Orion also has the capability to service the ISS as a backup to commercial crew and cargo delivery services now in development for the ISS. Orion will be capable of transporting crew to and from the ISS and staying for six months as a rescue vehicle.

Knowledge-Based Acquisition for a Path from the Past to the Future

Unlike NASA's past space vehicle efforts, such as the National Aero-Space Plane, X–33, and Orbital Space Plane, which focused on pushing technology and relied on numerous advances and breakthroughs, Orion is designed and focused on achieving clear national goals based on known technology and using an integrated management approach.

Our approach to Orion mirrors NASA's overall focus on technical competence and excellence in our workforce and in project development and oversight. NASA is placing greater emphasis on reliability in its systems and increasing the amount of up-front analysis that goes into concept definition to ensure that top-level requirements are known and achievable. We recognize that our systems like Orion will operate over decades and in different flight regimes. Therefore, we have decided to insert low-risk and mature technologies into the process but also allow for the introduction of new technology that can mature quickly. Orion resembles Apollo for good reason. Relying on proven technology for our lunar return increases the likelihood of success. Although Orion borrows its shape and aerodynamic performance from Apollo, the new capsule's updated computers, electronics, life support, propulsion, and heat protection systems represent a marked improvement over legacy systems. Our technology program is tightly coupled with the Constellation Program and it is essential to keeping our long-term risk and life cycle costs within bounds. Because of its importance to overall exploration program risk and our ability to meet national goals, we ask that you support full funding for our technology program's budget. We are working on a range of technologies, such as cryogenic storage and hydrogen fuel cells, that will make a big impact on our programs and may have valuable applications outside of the space program.

NASA is working to ensure that initial investments lead to an Orion system that supports multiple applications with low recurring operations and life cycle costs. Since recurring infrastructure costs have a substantial effect on life cycle costs, selection of the Orion launch vehicle, the Ares I, was influenced greatly by the contractor's ability to minimize infrastructure and associated manpower requirements.

Technology maturation activities by our research and technology development programs will further improve reliability, reduce life cycle costs, and increase the anticipated effectiveness of future exploration systems. Also critical to cost control will be the development of a versatile human-rated launch system. The Orion/Ares design will serve as an anchor for NASA's transportation architecture, which itself is intended to enable exploration involving multiple destinations and diverse objectives. The architecture will be able to grow so that it can perform multiple functions. The overall crew transportation system that will evolve from the basic design will enable ascent and entry in Earth's atmosphere, transit in Earth orbit and through deep space, and operations at multiple locations including the Moon and Mars.

Orion embodies a new generation of systems but it will be built upon the tried-and-true engineering of the past. We evaluated literally thousands of configurations and transportation options before settling on Orion's design. The Orion contract is a continuation of these analyses, requirements, architecture, and conceptual design work. Orion will enable space operations by U.S. astronauts on the Moon and elsewhere in the solar system. As the *NASA Authorization Act of 2005* also directed, we now have a very capable transportation architecture that infuses Shuttle-derived hardware and capabilities where appropriate. As a four-time space flyer, personal aircraft builder and flyer, and holder of a Ph.D. in aerospace engineering from the Georgia Institute of Technology, I am confident in the design we have chosen. This is not a technology dependent program. This is still rocket science—but rocket science we know and understand.

Orion Contract Approach and Strategy

The acquisition strategy for Orion and other projects within Exploration Systems need to match the bold and forward-thinking *Vision for Space Exploration.* Within Exploration Systems we have laid out acquisition strategy tenets that were followed for the Orion contract. One of these tenets is to maximize competition. From our recent down-select we received innovative and credible approaches with financial commitments from the Lockheed Martin team that will reap benefits for NASA through the entire life cycle of the Orion project. Another tenet that we are using for Orion and other elements of the Constellation Program is to utilize current, proven technologies that will lead to a safer, more reliable and affordable solution. Because NASA defined the design concepts for development by both Phase One contractors, both Prime Contractor teams were able to construct credible proposal estimates. Lockheed Martin will take these concepts to the next stage of development. For the Schedule A contract for the Design, Development, and Test and Evaluation phase for Orion, NASA chose a cost-type contract, in which it accepts all of the cost risks. We chose this type of contract in order for the contractor team to fully refine the design and test the vehicle so that NASA can receive a reliable and affordable space vehicle. What makes this cost risk acceptable is the fact that the NASA's two independent efforts—one performed by the Constellation Program Office and the other by the Smart Buyer team—included detailed preparatory work in its strategy for establishing firm requirements at the beginning of the contract. The "not to exceed" prices for the Schedule B option establishes the upper level of the contract value for the Agency for the production of the Orion vehicles to meet the current planned manifest. I would like to acknowledge Allen Li and his team at the Government Accountability Office for pointing out the potential long-term commitment in our solicitation which resulted in NASA making options of both Schedule B and C in the final contract.

NASA's acquisition strategy and plan for selecting a Project Orion prime contractor was based on a thorough business case and the efforts of our two NASA teams that developed independent designs. We were intimately familiar with both proposal teams, having worked side-by-side with each of them for over a year under Phase 1 contracts. The Orion Project will establish a firm foundation for the Constellation Program. The Orion acquisition strategy and plan focuses on gaining industry's commitment for a design solution and controlling life cycle cost through competition and incentives. NASA invested more than $140 million in the formulation phase and we had an appropriate level of knowledge to down-select a single Project Orion prime contractor.

From a contract oversight perspective, we will employ a number of measures to further guard against cost overruns. NASA based 25 percent of the award fee evaluation pool on project cost management. The project will employ earned value management, with cost and schedule performance measured against tasks. Progress will be measured through milestones and tests on a schedule determined by the program. We will demonstrate hardware and progress on Orion through an exacting test and demonstration schedule. Additionally, the Orion contract has an "end item" award fee feature that will be milestone based and focused on successful completion of all elements of the design and initial production of the Orion vehicle. We believe this award fee feature presents an opportunity to maximize the return on investment for both NASA and the Lockheed Martin team.

NASA's contract with Lockheed Martin maintains the longstanding development schedule for Orion. The initial flight test of an Orion prototype is targeted for 2008. The first unpiloted flight of an actual capsule will follow in 2011, and the first flight with humans aboard is to occur no later than 2014. Orion's first Moon mission with a crew will take place between 2015 and 2020.

The Orion Project organization was approved June 1, 2006, as a multi-center "virtual" organization that leverages the Agency's technical strengths. Staffing of key positions is complete. A Constellation tasks "roll out" to nine NASA Centers and the Jet Propulsion Laboratory occurred on June 6, 2006. The NASA centers included Ames, Glenn, Goddard, Langley, Kennedy, Marshall, Stennis, Johnson and Dryden. Management processes are maturing, with integrated reporting and scheduling processes instituted and maturing; boards, panels, and working groups identified; and configuration and risk management processes operating.

NASA Has Addressed the Findings of the GAO Report

NASA has reviewed the findings in the GAO Report entitled *"NASA: Long-Term Commitment to and Investment in Space Exploration Program Requires More Knowledge."* We have non-concurred with a key finding in the report since we feel we are meeting the concerns stipulated through our management framework, acquisition approach, and our incentives to Lockheed Martin to meet performance, schedule, and life cycle cost requirements. Also, as stated earlier, we are not seeking technological miracles. We are not trying to violate the laws of physics—we are ready to build a spaceship that can meet our current national needs and evolve to meet our future needs. However, although we non-concurred with the overall report, we have implemented a number of the GAO's recommendations.

NASA has learned and applied the best lessons from its past efforts. More importantly, we have adopted an implementation approach that is technically solid and well-managed. On the contract side, we have, after discussions with GAO, made the Schedule B and Schedule C portions of the contract into options. Phase Two preserves NASA's flexibility to terminate the contract at Orion's preliminary design review if cost projections are determined to be unaffordable and non-executable.

Progress Report—Meeting Commitments and Transitioning Access to Low-Earth Orbit

NASA is making good progress on the national objectives Congress has laid out for the Agency. Space Shuttle missions STS–121 in July and STS–115 this month brought us two steps closer to finishing assembly of the International Space Station and meeting our partner commitments. We also are two steps closer to retiring the Shuttle in 2010. The Exploration Systems Mission Directorate is working to create greater service-based access to low-Earth orbit, to utilize the ISS for exploration research and development, and to foster the capabilities necessary to sustain human presence on the lunar surface. In August, we entered into two unprecedented agreements with Space X and Rocketplane Kistler to demonstrate, based on milestone performance, cargo and crew services to support the ISS. We are very hopeful that these and other nascent commercial space efforts will succeed so that NASA can increasingly shift its focus and resources beyond low-Earth orbit. Once the commercial sector demonstrates this capability, then we will enter into Phase Two of the Commercial Crew and Cargo program and procure these services from the commercial sector via the competitive procurement process.

Meanwhile, much work on Orion already has been accomplished. In May, six vertical drop tests of a body mass simulator, in support of landing systems development, took place at Langley Research Center, and all Phase One arc jet testing for thermal projection systems was completed at Ames Research Center. In June, Ames and the Jet Propulsion Laboratory completed the first phase of a real-time operating trade study evaluation and delivered an interim report, and Orion thermal protection system material was arc jet tested at Johnson Space Center. In July, the Orion cockpit team conducted crew evaluations of proposed window designs and the flight test article System Requirements Review (SRR) was completed. This month we kicked off the Orion SRR and made the Phase Two contract award for the Thermal Protection System Advanced Development Project. In October, NASA will hold a Preliminary Design Review for the Orion flight test article. We are moving forward. On the Ares front, we now have models being tested in wind tunnels. We are firing engine components and will be conducting a launch abort test in 2008 and a full-scale Ares I–1 test launch in April 2009. The Lunar Reconnaissance Orbiter (LRO)/ Lunar Crater Observation and Sensing Satellite (LCROSS) mission is on track for launch in 2008.

Conclusion

The Space Shuttle is the world's most versatile spacecraft to date. The Constellation program's Orion and Ares will be even more so. They are designed to fly to the Moon, but they also may be used to service the International Space Station. We are looking at ways that Constellation will support expeditions to other bodies in the solar system after we are finished exploring Mars. The possibilities seem limitless. Most importantly, the Constellation Program and our Commercial Orbital Transportation Services (COTS) efforts will assure America's access to space after the Space Shuttle is retired in 2010.

Orion is the focus of America's 21st century crewed space transport strategy, designed to continue the evolution of exploration experience and cutting-edge technology that began with the Apollo Program. Orion will help further our understanding of Earth, the solar system, the universe, and the origins of life itself. It will support our exploration missions by providing crew ascent and entry into Earth's atmosphere, orbital and deep-space transit, transfer capabilities, and operations at the Moon, Mars, and elsewhere.

Mr. Chairman, thank you for the opportunity to testify before you today. I look forward to working closely with the Congress to ensure American leadership on the frontier of the future. I would be pleased to respond to any questions you or the other Members of the Committee may have.

BIOGRAPHY FOR SCOTT J. HOROWITZ

Scott J. Horowitz is the Associate Administrator for the Exploration Systems Mission Directorate. A former NASA astronaut and a retired U.S. Air Force Colonel, he will lead the Agency in the development of the Nation's new spacecraft that will return astronauts to the Moon and travel to Mars and other destinations in the solar system.

After retiring from NASA and the Air Force in 2004, Horowitz joined ATK Thiokol, Inc., as Director of Space Transportation and Exploration. At ATK, he was responsible for developing the company's strategy to support NASA's *Vision for Space Exploration.*

Horowitz joined the Air Force after graduating with a Master's and doctorate in aerospace engineering from the Georgia Institute of Technology. He received his undergraduate degree in engineering from California State University at Northridge.

During his military career, he was an instructor pilot, F–15 fighter pilot and, after attending the Air Force Test Pilot School, served an assignment as a test pilot. He has logged more than 5,000 hours in more than 50 different aircraft. Horowitz also served as an adjunct professor at Embry Riddle University and later as a Professor at California State University at Fresno.

NASA selected him as an astronaut pilot in 1992. A veteran of four Space Shuttle missions, Horowitz made his first flight in 1996 on a microgravity science mission. His other missions included servicing the Hubble Space Telescope and two flights to the International Space Station. He has logged more than 1,138 hours in space.

His decorations include the Distinguished Flying Cross, Defense Meritorious Service Medal, Defense Superior Service Medal, two Air Force Commendation Medals, two NASA Exceptional Service Medals and four NASA Space Flight Medals.

Chairman BOEHLERT. Thank you, Dr. Horowitz.

Mr. Li.

STATEMENT OF MR. ALLEN LI, DIRECTOR, ACQUISITION AND SOURCING MANAGEMENT, GOVERNMENT ACCOUNTABILITY OFFICE

Mr. LI. Before I begin, allow me to congratulate NASA, its employees, and contractors on its latest two achievements: Atlantis' successful mission, marking the long-awaited return to space station assembly, and Opportunity's breathtaking look at Victoria Crater. They are reminders of the excitement and challenges associated with space exploration, and the importance dedication and teamwork play in achieving mission success.

Chairman Boehlert, Ranking Member Gordon, and Members of the Committee, thank you for inviting me here today to discuss our work on NASA's efforts to implement its space exploration plans and the Crew Exploration Vehicle specifically. As requested, I will highlight my statement.

At the request of this committee, GAO initiated several reviews over the past year that have implications for implementation of the President's *Vision for Space Exploration.* In our December 2005 report regarding NASA's acquisition policies, we made several recommendations to help ensure NASA uses a knowledge-based acquisition approach to make informed investment decisions. More recently, in July of 2006, we issued a report that questioned the affordability of NASA's exploration program, and in particular, NASA's acquisition approach for the CEV, now known as Orion. Based on those reports, I will raise four issues.

Issue number one. NASA cannot develop a firm cost estimate for the exploration program at this time because the program is in its early stages. The current estimate is $230 billion over the next two decades. Changes that have occurred to the program over the past year illustrate its evolving nature. True, changes are appropriate and understandable at this early stage, but changes do not allow the Agency to firmly identify program requirements and needed resources, a key element of knowledge-based acquisition approach. Thus, we concluded that NASA was not in a position to make a long-term commitment to the program.

Issue number two. NASA will likely be challenged to implement the program as laid out in its exploration systems architecture study because of the high costs associated with the program in some years. Despite initial surpluses, the sustainability of the program is questionable, given its long-term funding outlook. NASA's preliminary projections show multi-billion dollar shortfalls for its Exploration Directorate in all fiscal years from 2014 to 2020, with an overall deficit through 2025 exceeding $18 billion. Furthermore, funds NASA is planning to have after 2010 made possible by the retirement of the Shuttle may not be available to the extent projected. This is because Shuttle transition needs are still being quantified.

Issue number three. NASA's acquisition strategy for the CEV was not based on obtaining an adequate level of knowledge to make an informed investment decision. NASA planned to commit the government to a long-term product development effort without a sound business case. This entails having well-defined requirements, mature technology, a preliminary design, and firm cost estimates that realistic budget projections can handle. Without such knowledge, it is difficult to predict with any confidence how much the program will cost, what technologies will or will not be available to meet performance expectations, and when the vehicle will be ready for use.

As you know, we recommended in our July 2006 report that NASA alter its strategy to reduce these risks by securing additional knowledge. NASA disagreed. However, as Dr. Horowitz's statement indicates, NASA subsequently adjusted its acquisition approach and now production and sustainment portions of the contract are options, a move that is consistent with our recommendation, since it lessens the government's financial obligation at this early stage. However, risks persist with NASA's approach. NASA still has no assurance that the project will have a sound business case in place at preliminary design review. Therefore, commitment to efforts beyond that point, even when limited to design and development activities, is a risky approach.

My final issue. NASA's current acquisition policies and project guidance do not include major decision reviews beyond the initial project approval gate, nor a standard set of criteria with which to measure projects at crucial phases. As we pointed out in our December 2000 report—2005 report, these decision reviews and development measures are key markers needed to ensure that project progress and decisions are based on the appropriate levels of knowledge. These markers can help lessen project risks.

In response to our recommendations, NASA stated that it would make several changes to bring its policies more in line with a knowledge-based approach. For example, NASA plans to add requirements for success at key junctures and require additional project decision reviews. While these changes are not yet implemented, recent briefings and discussion with NASA officials indicate that the Agency plans to do so in revised project program management policies.

NASA would be well-served by fully implementing our recommendations, thereby placing itself in a better position to lessen risks, obtain good program outcomes, and achieve mission success.

So where do we go from here? Orion is only one piece of the pie. Implementing the Vision over the coming decades will require hundreds of billions of dollars and a sustained commitment from multiple Administrations and Congresses. With a range of federal commitments binging the fiscal future of the United States, competition for resources within the Federal Government will be fierce. Consequently, as it proceeds with its acquisition strategy for Orion and other key projects, it will be important for NASA to ensure that its investment decisions are sound and based on high levels of knowledge. This will allow decision-makers to make informed decisions about where continued investments are justified.

From the perspective of the Congress, tools have recently been instilled for more effective oversight. Indeed, cost growth in excess of stated thresholds as well as information on technology and schedule risks must now be reported as required by the *NASA Authorization Act of 2005*. GAO stands ready to assist this committee in its oversight responsibilities.

Mr. Chairman, this concludes my oral statement. I will be pleased to answer any questions you or other Members may have.

[The prepared statement of Mr. Li follows:]

PREPARED STATEMENT OF ALLEN LI

Mr. Chairman and Members of the Committee:

I am pleased to be here today to discuss the National Aeronautics and Space Administration's (NASA) plans for implementing the President's *Vision for Space Exploration* (Vision).[1] NASA plans to spend nearly $230 billion over the next two decades—more than $31 billion of which will be spent in the next five years—to bring the Vision to reality.[2] In July 2006, we issued a report that questioned the program's affordability, and in particular, NASA's acquisition approach for one of the program's major projects—the Crew Exploration Vehicle (CEV).[3] My statement today, which is based upon that report and another report evaluating NASA's acquisition policies,[4] highlights our continuing concerns with the affordability of the exploration program and the acquisition approach for the CEV project, as well as the absence of firm requirements in NASA's acquisition policies for projects to proceed with development with the appropriate level of knowledge. Given the competing demands facing the Federal Government and an already troubling funding profile for the program, it is imperative that NASA implement the various aspects of the Vision in a fiscally prudent and competent manner. Our work was performed in accordance with generally accepted government auditing standards.

Summary

In summary, we found that because NASA's exploration program is in its early stages, the Agency cannot develop a firm cost estimate for the program at this time. The changes that have occurred to the program over the past year and the resulting refinement of its associated cost estimates are indicative of the evolving nature of the program. Furthermore, we found that it will likely be a challenge for NASA to implement the program, as laid out in its Exploration Systems Architecture study (ESAS)[5] due to the high costs associated with the program in some years and the long-term sustainability of the program relative to anticipated funding. Finally, we found that NASA's acquisition strategy for the CEV was not based upon obtaining an adequate level of knowledge when making key resources decisions, placing the program at risk for cost overruns, schedule delays, and performance shortfalls. These risks were evident in NASA's plan to commit to a long-term product development effort before establishing a sound business case for the project that includes well-defined requirements, mature technology, a preliminary design, and firm cost estimates. Furthermore, in our 2005 report on NASA's acquisition policies, we found that NASA's policies lacked major decision reviews beyond the initial project approval gate and lacked a standard set of criteria with which to measure projects at crucial phases in the development life cycle. These decision reviews and development measures are key markers needed to ensure that projects are proceeding with and decisions are being based upon the appropriate level of knowledge and can help to lessen project risks.

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[1] The Vision includes a return to the Moon that is intended ultimately to enable exploration of Mars and other destinations. To accomplish this, NASA initially plans to (1) complete its work on the International Space Station by 2010, fulfilling its commitment to 15 international partner countries; (2) begin developing a new manned exploration vehicle to replace the Space Shuttle; and (3) return to the Moon no later than 2020 in preparation for future, more ambitious missions.

[2] All cost estimates related to the Vision are reported as inflated ("real year") dollars.

[3] GAO, *NASA: Long-Term Commitment to and Investment in Space Exploration Program Requires More Knowledge,* GAO–06–817R (Washington, D.C.: July 17, 2006).

[4] GAO, *NASA: Implementing a Knowledge-Based Acquisition Framework Could Lead to Better Investment Decisions and Project Outcomes,* GAO–06–218 (Washington, D.C.: Dec. 21, 2005).

[5] The ESAS was an effort to identify the best architecture and strategy to implement the Vision. The architecture supports the development of a new CEV, Crew Launch Vehicle (CLV), a Cargo Launch Vehicle (CaLV), and other supporting systems. The architecture also calls for various Research and Technology (R&T) and Robotic Lunar Exploration Program (RLEP) projects. NASA's Exploration Systems Mission Directorate's Constellation program is responsible for the development of the CEV, CLV, and CaLV.

In our July 2006 report, we recommended that NASA adjust its acquisition strategy to ensure that sufficient program knowledge—to include well-defined requirements, mature technologies, a stable design, and realistic cost estimates—be attained prior to committing the government to a long-term contract. NASA did not concur with our recommendation and in late August awarded a contract for the design, development, production, and sustainment of the CEV to Lockheed Martin. However, prior to awarding the contract, NASA adjusted its acquisition approach and the Agency included the production and sustainment portions of the contract as options—a move that is consistent with the recommendation in our report because it lessens the government's financial obligation at this early stage. While these changes are positive steps, the Agency's acquisition strategy needs further refinement to conform to acquisition best practices. Given the approach that NASA has chosen, continued congressional oversight will be critical for ensuring that the program stays within cost and schedule goals. This is especially true given NASA's "go as you can afford to pay" approach, wherein lower priority efforts will be deferred, descoped, or discontinued to allow NASA stay within its budget profile. Competing demands within the Agency, coupled with a declining supply of federal discretionary funding requires due diligence on the part the Agency and Congress to ensure successful program outcomes. As our work has found, all too often, programs are allowed to proceed without adequate knowledge being attained at key phases of development. Without such knowledge, it is difficult to predict with any confidence how much the program will cost, what technologies will or will not be available to meet performance expectations, and when the vehicle will be ready for use.

Background

Despite many successes in the exploration of space, such as landing the Pathfinder and Exploration Rovers on Mars, NASA has had difficulty bringing a number of projects to completion, including several efforts to build a second generation reusable human space flight vehicle to replace the Space Shuttle. NASA has attempted several costly endeavors, such as the National Aero-Space Plane, the X–33 and X–34, and the Space Launch Initiative. While these endeavors have helped to advance scientific and technical knowledge, none have completed their objective of fielding a new reusable space vehicle. We estimate that these unsuccessful development efforts have cost approximately $4.8 billion since the 1980s. The high cost of these unsuccessful efforts and the potential costs of implementing the Vision make it important that NASA achieve success in its new exploration program beginning with the CEV project.

Our past work has shown that developing a sound business case, based on matching requirements to available and reasonably expected resources before committing to a new product development effort, reduces risk and increases the likelihood of success. High levels of knowledge should be demonstrated before managers make significant program commitments, specifically: (1) At program start, the customer's needs should match the developer's available resources in terms of availability of mature technologies, time, human capital, and funding; (2) Midway through development, the product's design should be stable and demonstrate that it is capable of meeting performance requirements; (3) By the time of the production decision, the product must be shown to be producible within cost, schedule, and quality targets, and have demonstrated its reliability. Our work has shown that programs that have not attained the level of knowledge needed to support a sound business case have been plagued by cost overruns, schedule delays, decreased capability, and overall poor performance. With regard to NASA, we have reported that in some cases the Agency's failure to define requirements adequately and develop realistic cost estimates-two key elements of a business case-resulted in projects costing more, taking longer, and achieving less than originally planned.[6]

Firm Cost Estimates Cannot Be Developed at This Time

Although NASA is continuing to refine its exploration architecture cost estimates, the Agency cannot at this time provide a firm estimate of what it will take to implement the architecture. The absence of firm cost estimates is mainly due to the fact that the program is in the early stages of its life cycle. NASA conducted a cost risk analysis of its preliminary estimates through fiscal year 2011. On the basis of this analysis and through the addition of programmatic reserves (20 percent on all development and 10 percent on all production costs), NASA is 65 percent confident that the actual cost of the program will either meet or be less than its estimate of $31.2 billion through fiscal year 2011. For cost estimates beyond 2011, when most of the cost risk for implementing the architecture will be realized, NASA has not applied a confidence level distinction. Since NASA released its preliminary estimates, the Agency has continued to make architecture changes and refine its estimates in an effort to establish a program that will be sustainable within projected resources. While changes to the program are appropriate at this stage when concepts are still being developed, they leave the Agency in the position of being unable to firmly identify program requirements and needed resources. NASA plans to commit to a firm cost estimate for the Constellation program at the preliminary design review in 2008, when requirements, design, and schedule will all be base-lined. It is at this point where we advocate program commitments should be made on the basis of the knowledge secured.

Expected Budget and Competing Demands Will Challenge Architecture Implementation

NASA will be challenged to implement the ESAS recommended architecture within its projected budget, particularly in the longer-term. As we reported in July 2006, there are years when NASA has projected insufficient funding to implement the architecture with some yearly shortfalls exceeding $1 billion; while in other years the funding available exceeds needed resources. Per NASA's approach, it plans to use almost $1 billion in appropriated funds from fiscal years 2006 and 2007 in order to address the short-term funding shortfalls. NASA, using a "go as you can afford to pay" approach, maintains that in the short-term the architecture could be implemented within the projected available budgets through fiscal year 2011 when funding is considered cumulatively. However, despite initial surpluses, the long-term sustainability of the program is questionable given the long-term funding outlook for the program. NASA's preliminary projections show multi-billion-dollar shortfalls for its Exploration Systems Mission Directorate in all fiscal years from 2014 to 2020, with an overall deficit through 2025 in excess of $18 billion. According to NASA officials, the Agency will have to keep the program compelling for both Congress and potential international partners, in terms of the activities that will be conducted as part of the lunar program, in order for the program to be sustainable over the long run.

NASA is attempting to address funding shortfalls within the Constellation program by redirecting funds to that program from other Exploration Systems Mission Directorate activities to provide a significant surplus in fiscal years 2006 and 2007 to cover projected shortfalls beginning in fiscal year 2009. Several Research and Technology programs and missions were discontinued, descoped, or deferred and that funding was shifted to the Constellation Program to accelerate development of the CEV and CLV. In addition, the Constellation program has requested more funds than required for its projects in several early years to cover shortfalls in later years. NASA officials stated the identified budget phasing problem could worsen given the changes that were made to the exploration architecture following issuance of the study. For example, while life cycle costs may be lower in the long run, acceleration of development for the five segment Reusable Solid Rocket Booster and J–2X engine will likely add to the near-term development costs, where the funding is already constrained. NASA has yet to provide cost estimates associated with program changes.

NASA must also contend with competing budgetary demands within the Agency as implementation of the exploration program continues. NASA's estimates beyond 2010 are based upon a surplus of well over $1 billion in fiscal year 2011 due to the retirement of the Space Shuttle fleet in 2010. However, NASA officials said the costs for retiring the Space Shuttle and transitioning to the new program are not fully understood; thus, the expected surplus could be less than anticipated. This year,

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[6] GAO, *NASA: Lack of Disciplined Cost-Estimating Processes Hinders Effective Program Management,* GAO–04–642 (Washington, D.C.: May 28, 2004).

NASA plans to spend over 39 percent of its annual budget for Space Shuttle and International Space Station (ISS) operations—dollars that will continue to be obligated each year as NASA completes construction of the ISS by the end of fiscal year 2010. This does not include the resources necessary to develop ISS crew rotation or logistics servicing support capabilities for the ISS during the period between when the Space Shuttle program retires and the CEV makes its first mission to the ISS. While, generally, the budget for the Space Shuttle is scheduled to decrease as the program moves closer to retirement, a question mark remains concerning the dollars required to retire the Space Shuttle fleet as well as transition portions of the infrastructure and workforce to support implementation of the exploration architecture. In addition, there is support within Congress and the scientific community to restore money to the Science Mission Directorate that was transferred to the Space Shuttle program to ensure its viability through its planned retirement in 2010. Such a change could have an impact on future exploration funding.

Lack of Sound Business Case Puts CEV Acquisition at Risk

In July 2006, we reported that NASA's acquisition strategy for the CEV placed the project at risk of significant cost overruns, schedule delays, and performance shortfalls because it committed the government to a long-term contract before establishing a sound business case. We found that the CEV contract, as structured, committed the government to pay for design, development, production and sustainment upon contract award—with a period of performance through at least 2014 with the possibility of extending through 2019.

Our report highlighted that NASA had yet to develop key elements of a sound business case, including well-defined requirements, mature technology, a preliminary design, and firm cost estimates that would support such a long-term commitment. Without such knowledge, NASA cannot predict with any confidence how much the program will cost, what technologies will or will not be available to meet performance expectations, and when the vehicle will be ready for use. NASA has acknowledged that it will not have these elements in place until the project's preliminary design review scheduled for fiscal year 2008. As a result, we recommended that the NASA Administrator modify the current CEV acquisition strategy to ensure that the Agency does not commit itself, and in turn the Federal Government, to a long-term contractual obligation prior to establishing a sound business case at the project's preliminary design review. In response to our recommendation, NASA disagreed and stated that it had the appropriate level of knowledge to proceed with its current acquisition strategy. NASA also indicated that knowledge from the contractor is required in order to develop a validated set of requirements and, therefore, it was important to get the contractor on to the project as soon as possible. In addition, according to NASA officials, selection of a contractor for the CEV would enable the Agency to work with the contractor to attain knowledge about the project's required resources and, therefore, be better able to produce firm estimates of project cost. In our report, we highlighted that this is the type of information that should be obtained prior to committing to a long-term contract. To our knowledge, NASA did not explore the possibility of utilizing the contractor, through a shorter-term contract, to conduct work needed to develop valid requirements and establish higher-fidelity cost estimates—a far less risky and costly strategy.

Subsequent to our report, NASA did, however, take steps to address some of the concerns we raised. Specifically, NASA modified its acquisition strategy for the CEV and made the production and sustainment schedules of the contract—known as Schedules B and C—contract options that the Agency will decide whether to exercise after project's critical design review in 2009. Therefore, NASA will only be liable for the minimum quantities under Schedules B and C when and if it chooses to exercise those options. These changes to the acquisition strategy lessen the government's financial obligation at this early stage. Table 1 outlines the information related to the CEV acquisition strategy found in the request for proposal and changes that were made to that strategy prior to contract award. While we view these changes as in line with our recommendation and as a positive step to address some of the risks we raised in our report, NASA still has no assurance that the project will have the elements of a sound business case in place at the preliminary design review. Therefore, NASA's commitment to efforts beyond the project's preliminary design review—even when this commitment is limited to design, development, test and evaluation activities (DDT&E)—is a risky approach. It is at this point that NASA should (a) have the increased knowledge necessary to develop a sound business case that includes high-fidelity, engineering-based estimates of life cycle cost for the CEV project, (b) be in a better position to commit the government to a long-term effort, and (c) have more certainty in advising Congress on required resources.

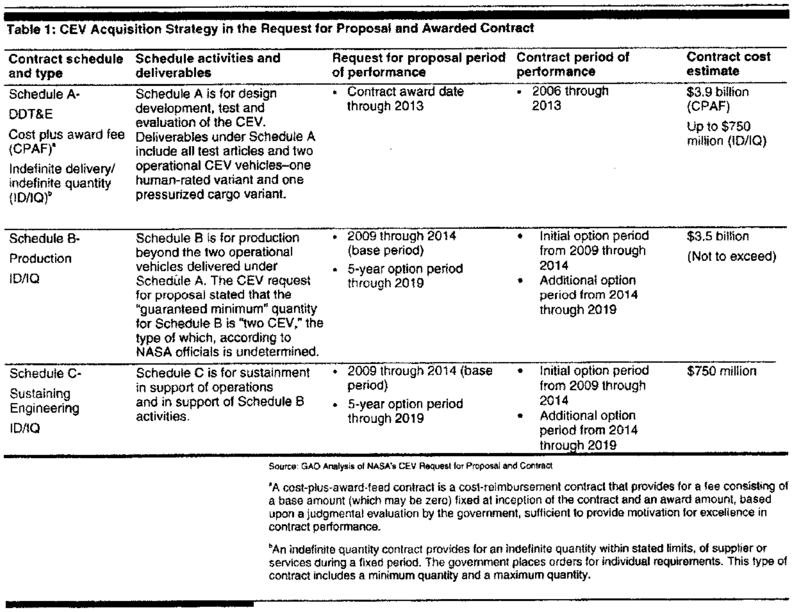


Table 1: CEV Acquisition Strategy in the Request for Proposal and Awarded Contract

Contract schedule and type	Schedule activities and deliverables	Request for proposal period of performance	Contract period of performance	Contract cost estimate
Schedule A- DDT&E Cost plus award fee (CPAF)[a] Indefinite delivery/ indefinite quantity (ID/IQ)[b]	Schedule A is for design development, test and evaluation of the CEV. Deliverables under Schedule A include all test articles and two operational CEV vehicles–one human-rated variant and one pressurized cargo variant.	• Contract award date through 2013	• 2006 through 2013	$3.9 billion (CPAF) Up to $750 million (ID/IQ)
Schedule B- Production ID/IQ	Schedule B is for production beyond the two operational vehicles delivered under Schedule A. The CEV request for proposal stated that the "guaranteed minimum" quantity for Schedule B is "two CEV," the type of which, according to NASA officials is undetermined.	• 2009 through 2014 (base period) • 5-year option period through 2019	• Initial option period from 2009 through 2014 • Additional option period from 2014 through 2019	$3.5 billion (Not to exceed)
Schedule C- Sustaining Engineering ID/IQ	Schedule C is for sustainment in support of operations and in support of Schedule B activities.	• 2009 through 2014 (base period) • 5-year option period through 2019	• Initial option period from 2009 through 2014 • Additional option period from 2014 through 2019	$750 million

Source: GAO Analysis of NASA's CEV Request for Proposal and Contract

[a] A cost-plus-award-feed contract is a cost-reimbursement contract that provides for a fee consisting of a base amount (which may be zero) fixed at inception of the contract and an award amount, based upon a judgmental evaluation by the government, sufficient to provide motivation for excellence in contract performance.

[b] An indefinite quantity contract provides for an indefinite quantity within stated limits, of supplier or services during a fixed period. The government places orders for individual requirements. This type of contract includes a minimum quantity and a maximum quantity.

Sound Management and Oversight Key to Addressing CEV Project Risks

Sound project management and oversight will be key to addressing risks that remain for the CEV project as it proceeds with its acquisition approach. To help mitigate these risks, NASA should have in place the markers necessary to help decision-makers monitor the CEV project and ensure that is following a knowledge based approach to its development. However, in our 2005 report that assessed NASA's acquisition policies, we found that NASA's policies lacked major decision reviews beyond the initial project approval gate and a standard set of criteria with which to measure projects at crucial phases in the development life cycle—key markers for monitoring such progress. In our review of the individual center policies, we found that the Johnson Space Center project management policy, which is the policy that the CEV project will be required to follow, also lacked such key criteria. We concluded that without such requirements in place, decision-makers have little knowledge about the progress of the Agency's projects and, therefore, cannot be assured that they are making informed decisions about whether continued investment in a program or project is warranted.

We recommended that NASA incorporate requirements in its new systems engineering policy to capture specific product knowledge at key junctures in project development. The demonstration of such knowledge could then be used as exit criteria for decision-making at the following key junctures:

- Before projects are approved to transition in to implementation, we suggested that projects be required to demonstrate that key technologies have reached a high maturity level.
- Before projects are approved to transition from final design to fabrication, assembly, and test, we suggested that projects be required to demonstrate that the design is stable.
- Before projects are approved to transition to production, we suggested that projects be required to demonstrate that the design can be manufactured within cost, schedule, and quality targets.

In addition, we recommended that NASA institute additional major decision reviews that are tied to these key junctures to allow decision-makers to reassess the project based upon demonstrated knowledge.

While NASA concurred with our recommendations, the Agency has yet to take significant actions to implement them. With regard to our first recommendation, NASA stated that the Agency would establish requirements for success at the key junctures mentioned above. NASA planned to include these requirements in the systems engineering policy it issued in March 2006. Unfortunately, NASA did not include these criteria as requirements in the new policy, but included them in an appendix to the policy as recommended best practices criteria. In response to our second recommendation, NASA stated it would revise its program and project management policy for flight systems and ground support projects, due to be completed in fall 2006. In the revised policy, NASA indicated that it would require the results of the critical design review and, for projects that enter a large-scale production phase, the results of the production readiness review to be reported to the appropriate decision authority in a timely manner so that a decision about whether to proceed with the project can be made. NASA has yet to issue its revised policy; therefore, it remains to be seen as to whether the CEV project decision authorities will have the opportunity to reassess and make decisions about the project using the markers recommended above after the project has initially been approved. Briefings that we have recently received indicate that NASA plans to implement our recommendation in the revised policy.

The risks that NASA has accepted by moving ahead with awarding the contract for DDT&E for CEV could be mitigated by implementing our recommendations as it earlier agreed. Doing so would provide both NASA and Congress with markers of the project's progress at key points. For example, at the preliminary design review, decision-makers would be able to assess the status of the project by using the marker of technology maturity. In addition, at the critical design review, the Agency could assess the status of the project using design stability (i.e., a high percentage of engineering drawings completed). If NASA has not demonstrated technology maturity at the preliminary design review or design stability at the critical design review, decision-makers would have an indication that the project will likely be headed for trouble. Without such knowledge, NASA cannot be confident that its decisions about continued investments in projects are based upon the appropriate knowledge. Furthermore, NASA's oversight committees could also use the information when debating the Agency's yearly budget and authorizing funds not only for the CEV project, but also for making choices among NASA's many competing programs. If provided this type of information from NASA about its key projects, Congress will be in a better position to make informed decisions about how to invest the Nation's limited discretionary funds.

NASA's ability to address a number of long-standing financial management challenges could also impact management of NASA's key projects. The lack of reliable, day-to-day information continues to threaten NASA's ability to manage its programs, oversee its contractors, and effectively allocate its budget across numerous projects and programs. To its credit, NASA has recognized the need to enhance the capabilities and improve the functioning of its core financial management system, however, progress has been slow. NASA contract management has been on GAO's high-risk list since 1990 because of such concerns.

Conclusions

In conclusion, implementing the Vision over the coming decades will require hundreds of billions of dollars and a sustained commitment from multiple administrations and Congresses. The realistic identification of the resources needed to achieve the Agency's short-term goals would provide support for such a sustained commitment over the long-term. With a range of federal commitments binding the fiscal future of the United States, competition for resources within the Federal Government will only increase over the next several decades. Consequently, it is incumbent upon NASA to ensure that it is wisely investing its existing resources. As NASA proceeds with its acquisition strategy for the CEV project and other key projects, it will be essential that the Agency ensure that the investment decisions it is making are sound and based upon high levels of knowledge. NASA should require that the progress of its projects are evaluated and reevaluated using knowledge based criteria, thereby improving the quality of decisions that will be made about which program warrant further investment. Furthermore, it will be critical that NASA's financial management organization delivers the kind of analysis and forward-looking information needed to effectively manage its programs and projects. Clear, strong executive leadership will be needed to ensure that these actions are carried out. Given the Nation's fiscal challenges and those that exist within NASA, the availability of significant additional resources is unlikely. NASA has the opportunity to establish a firm foundation for its entire exploration program by ensuring that the level of knowledge necessary to allow decision-makers to make informed decisions about where continued investment is justified. Doing so will enhance confidence in the Agency's ability to finally deliver a replacement vehicle for future human space flight.

Mr. Chairman, this concludes my prepared statement. I would be pleased to respond to any questions that you or other Members of the Committee may have.

BIOGRAPHY FOR ALLEN LI

As Director of the Acquisition and Sourcing Management Team, Mr. Li is responsible for leading GAO's work at the National Aeronautics and Space Administration (NASA) and for reviewing defense acquisition programs. He also serves as the Team's Director for Operations, managing day-to-day activities of a geographically dispersed group. Examples of recent work include NASA's efforts to develop and build the International Space Station (ISS), Crew Exploration Vehicle (CEV), the James Webb Telescope, and Shuttle alternatives for supplying the ISS; the Agency's management of its Deep Space Network (DSN); and NASA's implementation of its Integrated Enterprise Management Program. Defense work recently completed include identification of the risks associated with the development of the Navy's EA–18G electronic attack aircraft.

Prior to assuming his current duties, Mr. Li was an Associate Director in GAO's Energy, Resources, and Science Issue Area where he directed work on research and development, nuclear safety, and Department of Energy management issues. Over the past twenty-seven years at GAO, he has worked in several other units, including GAO's Transportation Issue Area where he specialized in aviation safety and air traffic control modernization. Mr. Li has frequently testified before Senate and House Committee and Subcommittees on civil and military issues. He also testified before the *Columbia* Accident Investigation Board following the tragic loss of the Shuttle *Columbia* and its crew.

Mr. Li has received several awards at GAO: the Comptroller General's Distinguished Service Award, two Comptroller General's Meritorious Service Awards, and Director and Outstanding Achievement Awards from several GAO units. He was selected for GAO's Senior Executive Service in February 1993 and designated Associate Director of Transportation Issues. Mr. Li has a B.S. degree in Aerospace Engineering from the University of Maryland. Mr. Li is married to the former Ellen Dziuszko and lives in Oak Hill, VA. They have two adult children, Christopher and Allison.

DISCUSSION

CONGRESSIONAL OVERSIGHT

Chairman BOEHLERT. Thank you very much, Mr. Li.

Let me start by asking you some of the questions I addressed in my opening statement, and when you respond, I would like Dr. Horowitz to respond to your response.

The questions were what specifically should Congress be doing and what documentation should we be seeking to keep a watchful eye on Orion development?

Secondly, and now that the contract has been awarded, what other steps should NASA be taking to avoid cost escalation?

Mr. LI. Your first question has to do with exactly the point that I just ended with, which is the tools are there. The NASA Authorization Act will require NASA to report to this committee on the progress and all the technical risks associated with its program. Those are some things that this committee did not have before. I believe that your use of those particular tools will be very important, and I think that for them to provide you with honest answers in terms of where the status is, is going to be extremely important.

The second question is one that I think we all have to be worried about. There are a lot of things that NASA can be doing. They have identified that they have reduced the risks. Obviously, in this particular case, I have indicated that I don't agree with them. I think that they have gone further than they should. Be that as it may, the contract is signed. Let us move on. I believe that at this point in time, what NASA needs to do is to abide and conform with the policies and management guidance that is going to be finalized, hopefully in the coming weeks, and that will provide for more knowledge-based decisions in the future.

Chairman BOEHLERT. Thank you very much, and Dr. Horowitz, just before you respond to that, let me point out—and I think Chairman Calvert and Mr. Rohrabacher before him, and Mr. Udall will agree—that essentially we have got the Nunn-McCurdy language in the authorizing legislation, and that is a tribute to the Subcommittee and to the foresight of one of our most valuable members who is no longer a member of the professional staff, Mr. Adkins, Bill Adkins.

Mr. Horowitz.

Dr. HOROWITZ. Thank you, sir.

The first question, what should we do, and we do have mandatory reports which we will provide to you on a timely basis. I believe we have been very good recently at providing all reports to this committee as requested, and we will continue to do so.

But I think we are going to go above and beyond that, and the way we are going to do that is with open communications. We are going to come and visit you and let you know. You won't have to wait for a report to let you know what is going on. I have charged my staff to make sure that when things are happening, we keep you informed. It is our job to keep those lines of communication so you know what is going on. You have every right to know how your program is going, and we are very proud to share it with you.

What should we do to avoid the cost of overruns? A day doesn't go by that I don't say this to my staff. This is all about performance, cost, and scheduling. Every day you need to ask yourself, whether you are working on a contract, whether you are working on a design idea, whether you are working on an integration issue, you always have to think about performance, cost, and schedule. Having that in the forefront of your mind will allow us to do things like implement some of the recommendations that GAO gave us on making our contracts more responsible and to give the government better value for its dollar.

So that is basically the mantra and those are the ways that we are going to avoid the cost overruns.

GAO'S RESPONSE TO NASA CHANGES

Chairman BOEHLERT. Let me commend you for the open dialogue—continuing openness and continuing dialogue with the Committee and the Members and the staff. That is essential.

Mr. Li, if you had to give a mark, how would you grade NASA's response to the GAO report?

Mr. LI. Well, I have to be honest with you. When I first got the written response to the draft report, I was disappointed since they non-concurred. But I do believe that the events that have occurred subsequent to that—and I believe that both Houses, both this particular Committee and the Senate, forced a better understanding and caused NASA and my team to get together, and we discussed our differences. And I believe that that was—as a result of that, as you indicated in your opening statement, I think that is what oversight is. That is what good government is. We were able to have them have a better understanding of what our concern was, and as a result, they modified the contract to have options. I think that was a step in the right direction.

Chairman BOEHLERT. Thank you, sir, very much. This Committee believes very strongly in oversight.

So often in the Congress we do good deeds with the best of intentions and pat ourselves on the back and say “Boy, wasn’t that great?” Let us go on to the next thing, and don’t pause to go back and see if what we did originally was the right thing and people are responding in the appropriate manner. So you have given us some good direction, and I want to thank you on behalf of the entire Committee.

With that, Mr. Gordon.

BUDGET CONCERNS

Mr. GORDON. Thank you, Mr. Chairman.

I am afraid that there is not going to be much done about our spiraling budget deficits over the next two years, but I think in the election of 2008, both on the Presidential and Congressional, it is going to be a major issue. And with that, there is going to be needed budget pressure. I am concerned about NASA being able to survive and get the increases that we are talking about. And so we may have to deal with not only not getting those increases, but it could get worse.

Now, let me—I want to—that is the context. I want to congratulate NASA in terms of the approach you took with the CEV in terms of not overreaching in terms of technology and trying to, you know, trying to do the job with reachable technology. I think that was a smart approach and I think it follows Mr. Griffin’s overall approach to things. I compliment you for that.

Now, in your non-concurrence letters, you were very confident about being able to complete on time and on budget, and in your testimony you have here today. And so since you have such confidence, would NASA be willing to accept a formal cost cap on the CEV program?

Dr. HOROWITZ. Well, I believe, sir, to answer your question, we actually are operating under a cost cap. The—I have been given a budget. I have to make this program fit inside that budget or we cannot do any of the other things that we want to do. If I allow the CEV development to run over cost and schedule, we are not going to be able to do the goals of going on to the Moon and beyond because what you see here——

Mr. GORDON. So then what are you going to do, then, if—that is your job, so you are going to keep it within cost, you say.

Dr. HOROWITZ. Right.

Mr. GORDON. So will you take money from the rest of the exploration program or from other agency activities?

Dr. HOROWITZ. Everything has to——

Mr. GORDON. What will you do?

Dr. HOROWITZ. Everything has to come out of my exploration budget due to the exploration. We are going to make our programs fit inside of exploration. You only have the three things I talked about before. You have performance, costs, and schedule, and you need a certain minimum performance, for example, getting the CEV to orbit and accomplishing that mission. You need more performance to get to the Moon——

Mr. GORDON. So if you take it out of exploration, then what if you just wind up with a CEV and nothing else?

Dr. HOROWITZ. Well, the other thing you have left is schedule. If you can't get the job done with minimum performance and you have only a certain number of resources——

Mr. GORDON. But if you are going to have to get into resources and you are doing away with—so are you just saying you will just keep stretching the bounds?

Dr. HOROWITZ. You have no choice. With a set number of resources to achieve a minimum performance, if you are falling behind, the only out you have to stay within your resources——

Mr. GORDON. So then if you are—again, you are saying very competently you are going to do this, so why would it not be appropriate to have a formal cost cap?

Dr. HOROWITZ. I can take that for the record. I don't know any reason why you wouldn't, but I can go back and discuss that with my staff.

[The information follows:]

Historically, cost caps have not proven effective in managing major NASA research and development (R&D) programs. Constraining the International Space Station (ISS) to $2.1 billion annually did little to control overall program costs. And while life cycle cost caps are regularly imposed on small, discrete projects (e.g., Explorer, Discovery) as part of the selection process, they are not easily adapted to major R&D efforts that extend far beyond the current budget horizon. In the case of large development programs such as Constellation, cost caps can be problematic as they depend on assumptions regarding outyear funding. The future priorities of the country are not known and can change over the life of the Constellation program.

At its early formulation stage, the Constellation Program is certain to face "unknown unknowns" as we continue to refine requirements, develop advanced technologies, and begin to integrate the various systems into an operational infrastructure to enable long-term exploration of the Moon and Mars. When Constellation moves into the implementation phase, after Preliminary Design Review (PDR) in the spring of 2008, design, cost, and schedule baselines will be established, and Program performance will be measured against metrics established at the various key decision points throughout the life of the program. At this juncture, NASA will submit Constellation project life cycle cost commitments to Congress. Under Section 103 of the *NASA Authorization Act of 2005* (P.L. 109–155), NASA is required to submit Major Program Annual Reports, the first of which shall include a Baseline Report that is to include an estimate of the life cycle cost for those programs. Under Section 103, NASA is required to report changes to the Baseline Report—including life cycle cost estimates—as part of the annual budget request. NASA will notify the Committee at other junctures, as necessary, if there are any adjustments to life cycle cost estimates. As such, NASA would advise against imposition of a formal statutory "cost cap" on CEV development.

Mr. GORDON. Okay. It looks like somebody may have already discussed it for you there. Do they have anything you want to add to it?

Dr. HOROWITZ. Well, the only other part is—which comes to my initial statement is one of the things that I will guarantee will drive the costs higher over time is if we have unstable funding for the program, and I can't provide stability to the project. Also——

Mr. GORDON. You can guarantee it will get more expensive if you have to stretch it out a long time, too.

Dr. HOROWITZ. Right, and the thing that usually happens is if you short fund a program in the near-term, you can guarantee that you will stretch it out and you will increase its costs in the long-term.

Mr. GORDON. Which again goes back to the original problem.

Mr. Li, GAO's July 17 report to us made the following recommendation. In light of the fact that—and I am quoting you—or the report, which is probably you. "In light of the fact that NASA plans to award the contract for CEV in September of 2006, Congress should consider restricting annual appropriations and limiting NASA's obligations for CEV project to only the amount of funding necessary to support activities needed to successfully complete the project's preliminary design review." Do you still stand behind that recommendation, and if not, why not?

Mr. LI. I do. I mean, the application of a knowledge-based acquisition strategy is one which within the body of work that we have conducted at GAO has proven and has shown that when you don't abide by those particular principles, which is not going beyond what your knowledge tells you, that you do run into trouble. I mean, the Committee has a great list of DOD programs and this particular committee is aware of one of them, being the NPOESS, that have great exceeded their costs and projected costs because of such things as faulty assumptions, and I will have to say, there are some programs that we have reviewed that have faulty assumptions associated with the use of heritage technology. That has happened. So I am cautious when I hear NASA indicate that this is low-risk technology.

My recollection is that people that were telling me about the space station not being very high technology. They are just modules up in space, and yet, I seem to recall a $5 billion increase somewhere along the line.

Mr. GORDON. Mr. Li, I want to give Dr. Horowitz a chance to respond. I guess what we are seeing here is this cloud of skepticism because of NPOESS and other things. We only want—we think—at least, I think that we have the best vets available at NASA now and they are doing the best job available, but there is this skepticism and the concern that you can't put 1,000 pounds of canaries in a 500-pound box.

And so what would be your response to Mr. Li's—or to that recommendation?

Dr. HOROWITZ. Well, sir, the thing that I wanted to bring out in this program is we talk about the knowledge and technology. This is much different than, for example, NPOESS, in that we know exactly what we want here.

One of the things—and to give the space station as an example, is the requirements kept changing, and guaranteed, if you keep changing your requirements: how big is it going to be, how many people are going to be on it, all that——

Mr. GORDON. What about the recommendation that Congress should consider restricting annual appropriations and limiting NASA's obligations for CEV project to only the amount of funding necessary to support activities needed to successfully complete the project's preliminary design review?

Dr. HOROWITZ. Well, this comes back to the point of the stable funding. We have a budget profile laid out to successfully execute this project, and if we short fund the project in the near-term when we are working our way to the preliminary design review, now with our contractor on board, we will guarantee to delay the execution of this project and not meet the milestones, and therefore actually the program will get more expensive, not less expensive.

Mr. GORDON. Well, Mr.——

Mr. LI. I disagree because there should not be a connection between funding and the different phases of an acquisition. You can still ensure that you have that funding in the future without breaking it at PDR, for example.

Mr. GORDON. I need to stop, but I guess the premise that we are concerned about here is this. I don't think it is a foregone conclusion that we are going to do this no matter what, and to some extent, you are saying okay, it can always be stretched out but it will cost more. Well that means ultimately there has to be some money coming in.

I don't know—you know, there is a point at which we might very well say this is too expensive, this is not working, let us stop, you know, cut our losses. And you seem to be working under the premise we are going to do it no matter what, and I am not sure that is what Congress is going to do. And so that is what we are trying to do is reach a point where if we can do it in a responsible way.

Chairman BOEHLERT. Mr. Calvert.

Mr. CALVERT. Well, I guess I got a little more positive attitude, but I would like to point out, too, by the way, the deficit isn't spiraling out of control. It has actually come down $109 billion, based on the CBO estimate, but that is another subject. I just thought——

Mr. GORDON. Are you satisfied?

TRANSITION CHALLENGES

Mr. CALVERT. We are making progress. We are happy to say—like I said, I just have a different attitude.

But I want to point out that there are some things that we do in this country that are extremely important, and I think this is one of them. One point that I want to make is that if we don't have this operational within the time constraints that you have set out, 2014—and this is, I guess, a question for Dr. Horowitz—what is going to happen to that labor force in Houston and in Florida?

Dr. HOROWITZ. Sir, this is one of the biggest concerns and something we work on every day is the transition. One of the reasons the designs look the way they do before you is one of the key elements of design was how do we make the most value of all the investment we have, not just in our hardware and our technology, but in our workforce, because the workforce is the key. It is the people. People say what does it take to make a rocket fly, and they say you talk to engines and propulsion. It is not that; it is the thousands of people that we have working——

Mr. CALVERT. Okay——

Dr. HOROWITZ. If we lose that support——

Mr. CALVERT. I remember, you know—we are about the same age, maybe you are a little bit younger, but the Apollo Gemini program, when we had that gap between the Apollo Gemini and the Shuttle program, what happened to the labor force then?

Dr. HOROWITZ. Sir, that was a disastrous time for NASA. We lived through that——

Mr. CALVERT. Okay. So we can't allow——

Dr. HOROWITZ. We lost all that capability——

INTERNATIONAL COMPETITION

Mr. CALVERT. We cannot allow that to happen, and not only that, if we are not in outer space between that so-called gap period between 2010 and whenever we successfully launch these vehicles, does that mean nobody will be in outer space?

Dr. HOROWITZ. Absolutely not, sir. We have had demonstrated to us that there are a lot of other countries very interested in going to space.

Mr. CALVERT. There is competition out there today, isn't there?

Dr. HOROWITZ. Yes, sir. Anybody who understands what this is all about is out there going to space. There are many other people.

Mr. CALVERT. You know, I was looking at the—you know, I was commenting with my seatmate here about the Ares V and the lift capability of that, and of course, we go back and think of the old Saturn, but that has a lift capability of what, approximately 100 tons?

Dr. HOROWITZ. This one can lift a little more than a Saturn V, about 125 metric tons.

Mr. CALVERT. One hundred twenty-five metric tons. What is the heaviest lift capability we have now?

Dr. HOROWITZ. It is less than the small rocket you see to its left, which is on the order of 20 to 25 metric tons.

Mr. CALVERT. Now, is there potentially other revenue streams that could be utilized for Ares V in other parts of the government?

Dr. HOROWITZ. Yes, sir, I am sure there are other people that might be interested.

Mr. CALVERT. You mean, there is no country in the world at this point that can launch 125 metric tons?

Dr. HOROWITZ. Sir, there is nobody else who has this capability.

MORE TRANSITION CHALLENGES

Mr. CALVERT. Okay. Now, you put together a pretty good contractor team, and the people who put this together, like you are saying, we are kind of going back to the future, as I have heard the slogan before. That the technology that you are using is—you are not going to use risky technology that has not proven itself. Is that a correct statement?

Dr. HOROWITZ. That is correct.

Mr. CALVERT. So you feel pretty comfortable that the budget you have set forth and the time constraints that you are under, you can meet?

Dr. HOROWITZ. Yes, sir, absolutely.

Mr. CALVERT. How confident would you say are you at controlling overall cost development of the Orion Crew Vehicle and also the Ares V?

Dr. HOROWITZ. Sir, we are very confident. We have all the technologies above what we call TRL [Technology Readiness Level] 6, so we don't see any issues there.

Mr. CALVERT. Okay.

Mr. Li, I do believe—I am a former business guy, you know, and I—when I was in the restaurant business we worked on a three percent margin. So I woke up every morning and tried to figure out what I was going to sell and what the profit margin was going to be, and just try to come out alive at the end of the day.

So obviously, we are dealing with larger numbers here, but when we are going through this process—and I think we are—I think Congress is committed to see this through. I think the country is committed to see this through. You know, from my perspective, I want to be on the Moon to greet the Chinese, not the other way around. That is just maybe a nationalistic statement on my part, but that is just the way I am.

But what should we do as a Committee as we move forward on this—what points would you think are most important to make sure that we have oversight to make sure that we keep this moving in the right direction and we maintain reasonable cost control as we move forward? And recognizing when you are dealing with new technology—I am on the Armed Services Committee, you know, the F–22 we didn't do too good.

Mr. LI. No.

Mr. CALVERT. And so—as a matter of fact, any—as you—and I know you work on DOD. We do a lousy job in the Department of Defense. I am hoping that NASA does a much better job than we do in the DOD on new weapons system procurement. As you know, on the new Joint Strike Fighter, I think that thing is out of control again, and my friends over here, I mean, we are going to have to get that brought in or we are not going to be developing that program.

So what can we do to stay on this to make sure that we keep control on this process?

Mr. LI. Thank you for your question. I think the issue here—and we touched on some of the points. You were raising the issue of the industrial base, I think is the way that I would characterize that in terms of with the Shuttle winding down, what happens to all those people. I am also worried, not only on those—of the people that they are using, but also their suppliers and also the various tiers of suppliers that go by. So I think that transition is extremely important.

I think the big challenge, sir, is going to be integration. I think the issue here is not just talking about the CEV, talking about the CLV, talking about the CaLV, it is the whole ball of wax. And I am encouraged because in talking with Dr. Horowitz, I understand that he is trying to build people within his team that will do that integration, but I think that is going to be a big challenge.

Chairman BOEHLERT. Thank you. The gentleman's time has expired.

Mr. Udall.

INTEGRATION CHALLENGES

Mr. UDALL. Thank you, Mr. Chairman.

Mr. Li, Dr. Horowitz, as I mentioned in my opening statement, I also serve on the Armed Services Committee, as does my good friend from California, Mr. Calvert. And from that vantage point, I have seen some of the problems that have arisen when we have tried to acquire space systems. And I wonder whether the DoD experiences for some reason for caution as we assess NASA's plans.

I wanted to read a couple of quotes this document, the Acquisition of National Security Space Programs Influential 2003 Joint Task Force. First, "Unrealistic estimates lead to unrealistic budgets and unexecutable programs. The space acquisition process is strongly biased to produce unrealistically low cost estimates throughout the process." And to another quote, "The government acquisition environment has encouraged excessive optimism and a can-do spirit. Program managers have accepted programs with inadequate resources and excessive levels of risk."

The Task Force then goes on to recommend that when estimating cost of space acquisition programs, "National security space programs should be budgeted at the 80/20 level, which the Task Force believes to be the most probable cost." As you know, NASA currently is using a lower competence level to estimate the cost of its CEV program, and the difference between NASA's cost estimate and the estimate we get when we follow the Task Force recommendation is $5.5 billion, not insignificant, which is also a significant increase in the estimated cost.

Mr. Li, GAO has done a lot of oversight on national security space programs, and you have looked at NASA's Exploration program now. Are there any parallels that from your point of view that we need to be concerned about as we evaluate——

Mr. LI. Thank you for your question, and I have had the opportunity to work on many of those programs. Mr. Calvert, actually for several years I monitored the F–22 program, well aware of the problems associated with Joint Strike Fighter (JSF).

But on the space acquisition, the space program specifically has been a real thorn in DOD's side. To DOD's credit, they are making some changes right now, recognizing that the things that they have done in the past, which is buying something all at once doesn't work. They are going to be a lot more careful in making sure that those things that they have to discover are going to be in science and technology. Once they have those technologies mature, they will bring that forward to—in the systems development process.

The things that NASA can learn from that is that there are some issues, as I indicated initially. They made some assumptions on programs like NPOESS and programs such as SBIRS High, programs that have identified the fact that technology, low-risk technology, that they were bringing from heritage type programs, actually did not pan out, and that is why I am cautioned—and I would like to think that some of these things that NASA are doing is going to be low-risk, but I think that from the standpoint of integration, when you are bringing—I recall when I had my old 1976 Dodge, I had the components for a car. The ones that I have right now on my 2000 Durango are quite different. They are the same components, but when they put them together, when I open that hood, I can't even figure out what hose is going to where. That is the issue. The components are probably basically the same, but once you integrate them, it is a completely different story.

Mr. UDALL. I think Chairman owns a '76 Dodge as well. But Dr. Horowitz, would you care to comment?

Dr. HOROWITZ. Oh, sorry. I have a '70 TR–6 I put a Corvette engine in, so that was quite an integration challenge. You can come to my shop any time.

No, absolutely. We have the same concerns. We worry about integration. This is a large integration task. We worry about doing it a piece at a time. These are the first two pieces. Our two pieces just happen to be a lot bigger. If you look at all of the things it is going to take for exploration, we are taking off bite-sized chunks at a time. They are just big bites because of the size of our vehicles that we fly.

Technology, again, I shall come back to. We are using as much known technology, and we do have technology lines. We have identified the top 40 technologies and when they are urged to support future programs. In fact, one of the things we can use your help and support in is making sure we can protect our technology investments because we do realize that if we don't invest in those early that later they will come to bite us, so we are prioritizing every single one of our technologies, tying to every place we need it to make sure that we get the development on time and on schedule, and we are using and the new guidance, which was from the recommendations from the GAO on the decision points and the key decision points are all being identified, and we are putting proper oversight and insight at each of those points.

Mr. UDALL. Thank you.

Chairman BOEHLERT. The gentleman's time has expired. Mr. Rohrabacher?

MORE BUDGET CONCERNS

Mr. ROHRABACHER. Well, let me admit that I don't know a darn thing about engines of cars, and I don't even know how to change the oil in my car, plus put parts in from other cars, et cetera, but one thing I do know about is getting the bill at the end of the month and trying to figure out how I am going to pay it. And what I am looking at here is I am trying to figure out what the bill is going to be at the end and how we are going to pay it.

Let me see if I can get this straight. Dr. Horowitz, to develop the Orion, the Ares I is the first of the two rocket parts of the Orion project. So how much will it cost us to get one of those rockets so that they are ready to go and do into space?

Dr. HOROWITZ. Okay, sir, the——

Mr. ROHRABACHER. The rocket? Now, you say you are going to use a lot of things that are coming from other rockets, so——

Dr. HOROWITZ. Okay, sir. Thank you for that question.

It is interesting in the development. We are developing a launch system, so what you will see is, you will see increase cost in the development of the Ares I and the reason that we are increasing the development is we have made some changes to make the parts more common between the Ares I and Ares V. We added the J–2.

We had originally based it on a Space Shuttle Main Engine, and so in order to drive down the lifecycle cost of the program, it was worth investing and developing that engine earlier, which will then not be needed to be redeveloped.

Mr. ROHRABACHER. Well, how much is the price tag at when you put the thing up? The first one?

Dr. HOROWITZ. Well, the whole development, I will have to take that for the record as the exact cost of the entire integrated development. The recurring cost that came of the estimates, including flying the capsule, was in the order of $200 million a flight.

Mr. ROHRABACHER. Okay, but how much is it going to cost us to get to the point to get to the recurring time period?

Dr. HOROWITZ. Well, I have the breakdown by the whole Constellation Systems. I can get you the breakdown by components if you like. I can take that for the record.

[The information follows:]

Launch vehicle costs for the Ares I Crew Launch Vehicle through the first human launch, currently projected late in FY 2014, are approximately $10.8 billion. This number excludes the Orion Crew Exploration Vehicle, mission and ground operations and facility modifications, and program integration and other program-level costs. Orion Crew Exploration Vehicle project costs through first human flight are about $10.3 billion. Therefore, combined Ares I and Orion project costs through first human launch are about $21.1 billion. If related required programmatic and non-flight hardware costs are included in the estimate, it will cost about $33.5 billion to get to the point of first human launch projected in 2014.

All of these numbers include reserves, but exclude Corporate G&A. These numbers include estimates for FYs 2012, 2013, and 2014, which lie beyond the budget horizon.

Mr. ROHRABACHER. Okay, so in other words, we are moving forward with both of these now——

Dr. HOROWITZ. Right.

Mr. ROHRABACHER.—and that is part of the same budget figure——

Dr. HOROWITZ. Yes.

Mr. ROHRABACHER.—so it is hard for you to break out what that first one is going to be?

Dr. HOROWITZ. Yes, sir. And I can go get you actual breakdown.

Mr. ROHRABACHER. Okay, but you are telling me that it is going to be $200 million a flight, starting what year?

Dr. HOROWITZ. The first human flights are scheduled—the operational flights will be in test in 2012.

Mr. ROHRABACHER. Right.

Dr. HOROWITZ. We will have the first fight test in 2009, but the full-up operation are scheduled for 2014.

Mr. ROHRABACHER. Yes, and that is $200 million a flight from that point on?

Dr. HOROWITZ. Right, and that is a functional flight rate, also.

Mr. ROHRABACHER. And you are guessing how much? Is it 30? Do I see the figure $31 billion here somewhere?

Dr. HOROWITZ. The overall program is about $30 billion for the horizon forecast out into the 2011 timeframe if you add up all of the cost for the entire Constellation program, which includes the launch vehicles, the Orion spacecraft, the ground systems, the technology program, the human-research program, and the robotics precursor programs, which will fly a mission to the Moon in 2008, and impactor, and a lander.

Mr. ROHRABACHER. And that is how much, all together, then?

Dr. HOROWITZ. All of that, integrated, to the 2011 timeframe is approximately $30 billion, total.

Mr. ROHRABACHER. Thirty billion, and then somewhere along the line, when we are actually going to get back to the Moon, it is going to cost us about $110 billion or something?

Dr. HOROWITZ. Sir, I don't know. I will take that for the record what the total is, but I just have the run out for the current budget out in front of me.

Mr. ROHRABACHER. Okay, so we are going to spend over $30 billion before we see that rocket go up. Is that right?

Dr. HOROWITZ. No, sir. You will see the first test flight of the Ares I——

Mr. ROHRABACHER. One——

Dr. HOROWITZ.—in 2009, which is several years before——

Mr. ROHRABACHER. Right.

Dr. HOROWITZ.—five years before years get to the end of that timeline.

Mr. ROHRABACHER. No, when I say go up, I mean actually be——

Dr. HOROWITZ. On an operational mission.

Mr. ROHRABACHER. Operational basis.

Dr. HOROWITZ. With people?

Mr. ROHRABACHER. Right.

Dr. HOROWITZ. Ready to go? Full-up? That would be about the total cost of the program to that point.

Mr. ROHRABACHER. Thirty-one billion dollars up until that point?

Dr. HOROWITZ. That is the number I have for the total run-out of the current budget.

Mr. ROHRABACHER. Mr. Li, do you think that is a realistic figure?

Mr. LI. Well, since I don't believe that the requirements have been fully established, I don't think that there is any confidence in what that number is, and we won't have a better idea of what that is until 2008.

Mr. ROHRABACHER. Okay. Until, 2008, all right. So let me ask you this: where is the money coming from in NASA for that money? Are we reducing spending elsewhere to make that money or is that coming out of a new type of potion that we have that creates wealth out of nothing?

Dr. HOROWITZ. Sir, thanks for that question.

The money needed to do this program is all of the money that has been allocated to the exploration line. And everything that we have laid out fits inside of the budget that we have been given. So we have put together a program that fits inside of the resources that have been allocated to us.

Mr. ROHRABACHER. You know, I would hope that some day someone who testifies somewhere before I leave would come and say, you know, we have just decided that a couple of these other projects have less value than the one we are talking about today, and we are going to get rid of two centers, two NASA centers. We have ten NASA centers. We are going to get rid of two of them in order to have a project to the Moon; and I have not heard that. I have been here 18 years, and I have never heard anybody talk that way.

Chairman BOEHLERT. Mr. Rohrabacher, you know my affection for you, so I am going to make you feel better. They are getting rid of the Shuttle. That is a good example.

Mr. ROHRABACHER. Well, that is a——

Chairman BOEHLERT. So do you feel a little bit better?

Mr. ROHRABACHER. I do feel better.

Chairman BOEHLERT. All right. That is good. And the gentleman's time has expired.

Mr. ROHRABACHER. Well, thank you very much.

Chairman BOEHLERT. Mr. Green?

Mr. GREEN. Thank you, Mr. Chairman and Ranking Member. As we go back to the future, my fear is that we may come back to the past. We are talking about, as I understand it, $122 billion through 2018, and let me just start by asking if that is a correct number for Constellation costs. Is that correct, $122 billion through 2018?

Mr. LI. Yes.

Mr. GREEN. Given that as correct, and understanding that sometimes we have persons who see very large coffers and they spend rather lavishly, what do we have contained within this to ensure us that we won't buy $500 hammers that we can go out to the hardware store and purchase for, shall we say, considerably less, or that we won't buy toilets seats for hundreds of dollars that we can purchase for considerably less. And I say this only because it has happened. This is not something that would be unique if it occurred as we go back to the future. So would one of you fine men care to elaborate, please?

Mr. LI. Well, you know, I don't think that based upon the fact that, as I indicated, the requirement have been sufficiently identified. I cannot with confidence tell you that there won't be any cost grown. I think that a lot of the technologies that they have identified are things that do make sense. I have to hand them that much, but the fact of the matter is there are a lot of things that we don't know yet, and some of those things will happen during testing, during integration. And at that point in time, as we know more, then, we will be able to make some better projections. But I think NASA is the one that needs to answer you question.

Dr. HOROWITZ. Yes, sir. And thank you for that.

The idea of runaway costs on individual items, the way you control costs in a program is you design analysis cycles, we are in our second iteration of design analysis cycles. We have already designed this vehicle four times, so we are actually gaining knowledge and getting a higher confidence in our estimates.

When you start the program and you just say I want to go the Moon, you have some initial concepts, and you make some estimate using the estimating tools. As you get further into the design, you get better a better cost estimates until eventually, when you finally build it, of course, you know you are at 100 percent. So we are improving our cost estimating every single design cycle, and in fact, we are in a cycle right now which will provide us an even higher confidence in our estimate. We actually have a signed contract for a vehicle——

Mr. GREEN. If you would, Doctor, allow me to interrupt for just a moment. Give your guesstimate as to how sure you are of this. Let us assume you could be 100 percent or you could be something less than 100 percent. How sure are you that we could avoid the concerns that I have called to your attention?

Dr. HOROWITZ. Well, sir, I am extremely certain that we can avoid these because we are going to implement a lot of the tools——

Mr. GREEN. Is that 100 percent?

Dr. HOROWITZ. I am 100 percent certain that we can avoid these problems with proper program management and proper oversight.

MORE TRANSITION CHALLENGES

Mr. GREEN. Okay. Now, another question, quickly, and this one has to do with the integration of people as opposed to equipment. If we integrate as we assume we will, what percentage of person will be lost from the project, will actually lose their jobs?

Dr. HOROWITZ. Sir, thank you for that question. It really comes to one of the hearts of why this transition is so important to all of us. Basically, the NASA budget is fairly flat. We know what it is; we know what percent we spend on the workforce inside of NASA and how much we spend on our contractor workforce. That number is not going to change; therefore, the number of jobs and the number of people aren't going to change. What we need to do is transition the workforce to do different things. We need the same number of people doing different things. Will there be some people displaced in the transition? Absolutely. Our goal is to keep as much and all of the talent we need to accomplish——

Mr. GREEN. Reclaiming my time for just a moment. Will most of those people be at the upper level, lower level or mid-level that we will lose?

Dr. HOROWITZ. Sir, I don't have an estimate at which level which people will be lost. There will be a transition at every level at every program.

Mr. GREEN. My assumption is that you will need the engineers, so we won't lose a lot of engineers. Is that a fair statement?

Dr. HOROWITZ. Well, we are going to need engineers, technicians, operators, production people, managers, program managers, project leaders at all levels.

Mr. GREEN. But at this level, you have no ideas where you will suffer your losses in terms of personnel.

Dr. HOROWITZ. I don't have any hard numbers to tell you exactly which positions at which level that are going to be lost. We are working on the transition plans at this time.

Mr. GREEN. And when do you anticipate having that type of intelligence?

Dr. HOROWITZ. Well, the estimates will get better all the time. I can take that for the record and get back to you with our current, rough estimate, and then as they improve, we can provide you as the transition plan progresses, more accurate estimates.

Mr. GREEN. I would be honored if you would.

Dr. HOROWITZ. It would be my pleasure, sir.

[The information follows:]

Civil servants currently supporting the Shuttle Program are generally either part of the operations infrastructure at Kennedy Space Center, or perform core human space flight functions (training, equipping humans to fly in space) at Johnson Space Center (JSC) and Marshall Space Flight Center (MSFC).

Since the Constellation Program relies upon certain Shuttle-derived technologies, we expect to find some commonality in hardware and operations requirements as we transition from Shuttle to Orion. At the same time, we are aggressively pursuing systems and processes that will allow us to operate more efficiently and effectively as we develop the Nation's new space capabilities. This effort includes commercial and international partnerships that could lower operations costs and better position us to achieve the *Vision for Space Exploration*'s goals.

During FY 2006, the Exploration Directorate embarked on a joint workforce review with Space Operations and NASA's Program Analysis and Evaluation group to study these very issues. The team completed the first of its planned center assessments at JSC in July, and will be visiting MSFC in November. The results of this study will feed into the FY 2009 Budget process, which will focus on the Shuttle-Orion transition.

Mr. GREEN. And I thank you. I yield back the balance of my time.

Mr. CALVERT. [Presiding] I thank the gentleman. Mr. Hall, you are recognized.

CEV SAFETY

Mr. HALL. I thank you, and I thank the chairman for having this, another good meeting. And I am thankful, also, for Dr. Horowitz, his history, his present, and what he going to be doing for us in the future. Both of our witnesses have alluded in their testimony the next few years are critical for NASA and the vision for space exploration.

The Committee in particular is going to need to really exercise its oversight power to make sure that the vision stays on track and that we meet our stated milestones, and you have indicated 100 percent sure if you do that, and there is always an allowance for when they don't do it exactly right; then that percentage would be affected, plus or minus, but getting a CEV going now is very critical to us if we are going to shorten the gap between the retirement of the Space Shuttle—we know we are going to do that—and the Orion mission.

I just have a couple of questions relating to the design of the CEV and the overall contract. As the Committee knows, I am not the only strong proponent of astronaut safety. We are all up here, every one us have that deep down in our crawl, and that has affected us back through the years of setting budgets and knowing that we have had to set them with safety in mind and knowing the effect that had on the budget and the increased increment of the budge for that, but we couldn't take a chance on that. I got funding in this for a study of crew escape mechanism for the Shuttle a couple of years ago. I can't remember exactly what it was. It seems like it was $15 million, somewhere along there.

And somewhere along the way we, during one of the discussion of the budgets here, we found out they had third-based some of that money to send John Glenn—and I am for sending old people up into space; I am all for that—but we got that finally place back and the money spent, and NASA explained to us that a mechanism just wasn't feasible for the Shuttle, and that is disturbing to know, but understanding the nature of the thing and the context and the weight of it, but they assured us that it is going to be part of the design of the next space vehicle, so Dr. Horowitz, give us some encouragement, and explain how the Orion is going to incorporate this crew-escape system, its effect, and its estimate of cost, if you can.

Dr. HOROWITZ. Yes, sir. Thank you very much.

As I stated in my testimony, the drivers to the design you see before you were based on the most important point you bring up, which is the crew getting to and from orbit. That requirement drove the entire design, so from the outset, the design allows for safety. The Shuttle, as a magnificent vehicle as it is, its complexity, and the fact of its basic layout, doesn't allow for an effective escape system. This vehicle, the escape system is depicted here by the small tower on the top, and it is very similar to what you may remember in the Apollo era which was tested on a Little Joe rocket. In fact, we just had meeting today to go over the design of the system that will test that escape system, which will be the first major test.

That system is called the launch abort system, and it is designed in the vehicle so that if you—first you design a very reliable vehicle you hope never has a bad day. That gets your chances up. Then if you have a bad day, you have a plan B. And we had some of the world's best safety and reliably experts looking at all of the design trades. We went through 20,000 to 40,000 of those, and the prediction is that this vehicle will enjoy, at least, an order of magnitude improvement in crew safety compare to our current Shuttle system.

And it is built into the cost estimate of the CEV. Part of what you get with the CEV contract is the capsule and its service module, its adapter, and the launch abort system; it is all part of that entire contract, so you get all of that with this contract.

Mr. HALL. And the estimate of the cost of the safety equipment?

Dr. HOROWITZ. Sir, I will have to take that for the record. I do not know the exact breakdown of the launch escape system, but I can get those numbers for you.

[The information follows:]

NASA does not currently track Orion CEV costs in a way that allows the determination of the cost of the Launch Abort System and other components. NASA is currently working with the Orion Prime Contractor on a contract modification that will, among other things, modify the Work Breakdown Structure (WBS) to allow collection of costs by Service Module, Crew Module and Launch Abort System. This work will be complete in the early spring 2007 to support the activities for the FY 2009 budget cycle.

Mr. HALL. Now, you are going to hear a lot from us about safety from this point forward, and I think you expect that, and I think you encourage it. And I do, once again, feel good with you where you are, and thank you for you service to this committee, to this Congress, and to this country. And I yield back.

Dr. HOROWITZ. Thank you, sir.

Mr. CALVERT. Mr. Ehlers.

PERFORMANCE MARGIN

Mr. EHLERS. Thank you, Mr. Chairman. First of all in response to the question asked by Mr. Rohrabacher asked a bit earlier, I have a different perspective, but for the same question, basically.

And I think a basic problem, Mr. Rohrabacher, is it is usual story of Congress wanting more than it is willing to pay for. And I think we have given NASA—put them in a horrible vise, saying yes, we want to finish the Space Station. Yes, we want to keep the Shuttle flying. Yes, we want the CEV. And we don't want you to cut anything else. But in fact, they can't do that. So we see Aeronautics being cut at a very crucial time when our air traffic control system, badly, over the next decade, is going to need huge revamping. The FAA simply cannot do it themselves; they were depending on NASA.

And so that leaves us an unresolved issue. In addition, the lack of funding for the many science experiments we can do, the various robotic devices, which as you know, cost much less than human space exploration, this is not a criticism of you, Dr. Horowitz. It is a criticism of Congress for having a bigger wish list than their pocketbook. But I think that is left you in a bit of a conundrum. But I am concerned; I still remember the X–33.

I made a trip to California on behalf of the Committee. Several of the Members here were along. I came home from that trip convinced it would never work. I talked to people about it. The project went on. Finally it was killed. I think your final net investment and loss was between $2 and $3 billion. I am very worried about making these great predictions on the basis of something that you are not very far along. And I realize that you are using a tried and true method, but there are still problems when you put it together, when you add an extra stage to the Ares I rocket, et cetera.

One concern I have is it is my understanding—and I may be wrong. If so, I would be delighted to be corrected. My understanding is that you want a performance margin between the weight of the rocket and its thrust, about an excess thrust of 20 percent for normal rockets and 30 percent for Human-Rated Rocket. Is that correct, or is there a different performance margin that you are current planning to achieve with the Orion plus the Ares rocket?

Dr. HOROWITZ. Sir, thank you for that question. I also went out to California and visited the X–33 and had the very same feelings. It was trying to violate the laws of physics, and that is expensive.

Mr. EHLERS. Well, that was interesting, and I got into an argument with the engineers there, and they just kept insisting I just didn't understand.

Dr. HOROWITZ. I got the same response.

Mr. EHLERS. And I asked them for a response in writing so they could take time to clarify it for a poor, ignorant physicist, and the letter made no sense either.

Dr. HOROWITZ. And I was a poor, ignorant aerospace engineer, and they treated me the same way.

Mr. ROHRABACHER. Mr. Ehlers, just for the record, there was an alternative to that project in the DC–X, which was supposed to be manufactured in my district, and the last administration chose the riskier proposition instead, let me note.

Mr. EHLERS. At any rate, back to the performance margin.

Dr. HOROWITZ. Yes, sir. Let me discuss a little bit about performance margin. And I appreciate that question.

The way we treat performance margin is several ways. The launch vehicle itself has margins, so we will ask the vehicle to lift, say, 50,000 to a certain orbit. The project manager for the launch vehicle is keeping performance margin for his launch vehicle, so the vehicle may be able to lift 50,000 pounds, and his margin is on the order of about 15 percent or so for the launch vehicle. We also have margin that the CEV project manager has to hold on his side in case his vehicle gets large, also.

The integrated margin, right now, is for the total Moon mission, not just the low Earth orbit. We have huge margins to get to low Earth orbit. But to be able to carry up to the lunar mission, approaching 20/20 at this point, we have about 25 percent performance margin on the amount of lift this vehicle can provide. And the very first test we did of the first engine component showed that it is exceeding its performance spec, but we are still going to keep the margin because you don't know where else you are going to need that margin.

Margin is very important in a program like this, and that is why you don't want to over promise and say you only have one percent of weight margin or something. That is not realistic in this program. We do have sufficient margins for working on the program.

Mr. EHLERS. Let me just tell you my concern on this because I have seen this with project after project including experiments I have worked on.

Dr. HOROWITZ. Right.

Mr. EHLERS. You are going to want to do more things: you are going to want to have more in the launch vehicle. If you can increase the margin on your propulsion system, then you start losing margin as you lose more goodies, perhaps an escape mechanism, to the capsule. I just feel very nervous about the margin you are using because I feel that is what might disappear as you go thorough the project and get lessened.

Dr. HOROWITZ. Well, sir, thank you. As I said, again, we guard the margins very closely.

One of the nice things, for example, on the first stage, we have already fired that engine. We know what it can do; so therefore, you have margin on a piece of equipment you already—so there is no much risk you are not—that you are not going got meet your performance spec even though you have the extra margin. One of the things that will eat your margin is if you change your requirements. It comes back to the overall——

Mr. EHLERS. That is what I am talking about. You are going to want more payload because you are going to think of extra things you are going to have to have for safety or other reasons.

Dr. HOROWITZ. Yes, sir. And since we have already included the escape system, the key thing that I have to do is maintain stability for the program by not letting excess requirements creep in from the top to ask the program to do more than the have the margin to protect. It is absolutely critical.

Mr. EHLERS. Actually, I think they will probably creep in the bottom as well.

Dr. HOROWITZ. I shall work on that, too, sir.

ARES ROCKET DEVELOPMENT

Mr. EHLERS. Just one last question: do you think that adding a fifth stage to the Ares rocket is a straightforward type of thing or do you anticipate some potential problems there?

Dr. HOROWITZ. Sir, thanks, I appreciate that question. I believe you are referring to the fifth segment on the first stage.

Mr. EHLERS. Yes, right.

Dr. HOROWITZ. The five-segment rocket booster was originally designed for the Shuttle program years ago. It actually was developed, and a five-segment version of the motor was tested in October of 2003. So it is already been fired and tested, and even using components that were still the old four-segment components that weren't upgraded, they still had plenty of margin to fire the motor and run it safely. So we believe that the risk to developing the five-segment is very low because we have already fired a full-scale motor.

Mr. EHLERS. And what propellants are you talking about using? I understand you are not——

Dr. HOROWITZ. We looked at that HT-type propellants and the P-ban, and for safety and manufacturability and cost, we stayed with the P-ban. If for some reason, you wanted to go to a higher performance motor, you could go to a higher performance propellant, but in the overall trade for the cost-effectiveness and the performance requirement and the manufacturability and the safety, we stayed with the P-ban, which is what we currently have in the Shuttle solid rocket motor.

Mr. EHLERS. Okay, I have a multitude of other questions, but I have had more than enough time.

Mr. CALVERT. Okay. I thank the gentleman. Mr. Akin, you are recognized.

PAYLOAD CAPACITY

Mr. AKIN. Thank you. I apologize for coming in a little bit late, so I don't know if I may be asking something that has already been asked. You are talking about going with the smaller model than you have there, and that is 100 percent solid fuel type approach, right?

Dr. HOROWITZ. Sir, the model that you see in front of you, the first stage is solid rocket propellant.

Mr. AKIN. Okay.

Dr. HOROWITZ. The second stage is LOX hydrogen.

Mr. AKIN. Okay. But you are not using your hydrogen and oxygen until you get further up?

Dr. HOROWITZ. That is correct, sir.

Mr. AKIN. And you are using, what was it? Ammonium perchlorate? Or aluminum or something?

Dr. HOROWITZ. That is the basic constituent of the solid rocket propellant.

Mr. AKIN. Right. Yes.

Dr. HOROWITZ. It is the same one we use in the Shuttle today.

Mr. AKIN. Right.

Dr. HOROWITZ. It is referred to as a P-ban propellant.

Mr. AKIN. Now, does that mean that you are taking less payload on that first than what you are taking currently, or how does the actual size of these, scale-wise——

Dr. HOROWITZ. Sir, to relate it, I can relate it to the Space Shuttle, if that is what you would like.

Mr. AKIN. Yes.

Dr. HOROWITZ. The payload being the Space Shuttle will bring up about 30 to 40,000, but it also brings up 200,000-pound Space Shuttle.

Mr. AKIN. Yes.

Dr. HOROWITZ. This launch vehicle, which is a solid rocket booster, at its second stage, can lift about 50,000 pounds to orbit, which is more than the payload being the Space Shuttle. To be able to go to the Moon, the large vehicle that you see to your left, my right, that vehicle could lift about 260-, 270,000 to orbit, about 125 metric tons, which is more than the Saturn 5 could lift to orbit.

Mr. AKIN. I am not that fast with the numbers. Compared to what we are lifting when we put a Shuttle up right now, the smaller model that you have, will that lift that amount or not?

Dr. HOROWITZ. Sir, that will lift more payload than the Space Shuttle can lift in its payload bay today.

Mr. AKIN. Right today? Then the bigger one is going to be quite a number of times more?

Dr. HOROWITZ. It is going to be approximately five times that much payload capacity.

Mr. AKIN. Five times more, okay. And the cost estimates and all, you have got that reasonably within projecting/including inflation and all in numbers, and you still think you are——

Dr. HOROWITZ. Yes, sir. We do. We do the standard. We include the stationary, and we include all costs, full costs accounting for all of the NASA workforce and all of the infrastructure and all of the development costs and all of the operations costs.

Mr. AKIN. I guess one last thing. I think I have still got another nickel in the meter here time-wise. What is going to be the purpose of these vehicles? Is it mostly just getting payload up into orbit or are you staring to push more forward than that and does that change the design of what you are doing? Or mostly are we just trying to put mass up to where we can start using it?

Dr. HOROWITZ. Sir, thanks for that question. That is the basic job of the launch vehicle, to get you to orbit. These vehicles were designed to get us to the Moon and then on to Mars, so the first vehicle is optimized to get the crew to lower Earth orbit. The large vehicle brings up all of the parts and pieces you need to, for example, bring a lander and extra fuel to get you to the Moon or to bring up the major parts you need when you eventually go to Mars some day.

Mr. AKIN. We use a jet-type technology to move the vehicle through space. Are we still using that? Would that be a hydrogen/oxygen type thing?

Dr. HOROWITZ. Sir, we have several different types of engines. The propulsion system that will propel you to the Moon, the engine we will use is the same engine we will use on the second stage, so we will use the same engine on the large vehicle, which is an oxygen and hydrogen rocket engine that will propel the whole stack to the Moon. We also have some other fuels that we use for storability for long-term storage on the Moon or on the way to Mars.

Mr. AKIN. I see, and basically the oxygen/hydrogen, weight-wise, gives you more performance than the solid does?

Dr. HOROWITZ. Yes, sir. The most efficient chemical propellant is oxygen and hydrogen. The reason we don't use it on the lower stages as much is it is not as much thrust even though it is more fuel efficient. As you get further from the earth, you want a more efficient fuel.

Mr. AKIN. I got it. So there are benefits of both, depending where you are using it.

Dr. HOROWITZ. Absolutely.

Mr. AKIN. Thank you very much. Thank you, Mr. Chairman.

Mr. CALVERT. I thank the gentleman. Mr. Udall.

MORE ON GAO'S RESPONSE TO NASA CHANGES

Mr. UDALL. Thank you, Mr. Chairman. Mr. Li, NASA—and Dr. Horowitz, I tell you, I want to give you a chance to reply as well. NASA asserts that implementing GAO's acquisition approach would delay the delivery of the CEV and increase costs. Do you agree or disagree and why?

Mr. LI. I think this goes back to our initial point. I think NASA chose to interpret our recommendation as necessarily taking two vendors and continuing with two. That is one way in which you can meet our recommendation. Now, obviously, if you have two vendors, it is going to cost more. But I, again, going back to my analogy of what my youth is with automobiles. The logo was pay me now or pay me later, and I think in this particular case, having more knowledge would have reduced those costs in the future years.

Now, there are other options that NASA could have taken. They took one which they decided to make options Schedule B and Schedule C. But I still believe that they went further than we would have liked; they would have been better served to only go through what we call preliminary design review. So from that perspective, it is very difficult to say whether or not those costs would be greater.

In terms of schedule, again, it goes back to that issue of are you going to have problems. I think that past history has shown, and with our experience looking at many DOD programs, the fact of the matter is if you don't have that knowledge, that is going to come back to bite you later on.

Mr. UDALL. Thank you. I am not sure Dr. Horowitz used Fram on this car. You remodeled it and you reengineered it. You are free to respond to the questions, but I also want to throw another one at you, which is can you provide your best quantitative estimates of the size of the delay and cost estimates if, in fact, the assertion you make is—were to hold fast?

Dr. HOROWITZ. Well, sir, thanks for allowing me to respond to that question. The first issue that Mr. Li brings up was actually, in my opinion, was just a failure to communicate. You can see there was some misunderstanding of our interpretation of his report, and that is why it was important for us to sit down and get together and we did make some modifications, like he pointed out. We added the options B and C.

The important thing for us is as we went through the design analysis cycles, a couple of things were happening. We had two contractor teams on board in a competitive environment, and that is always good to have competition to keep costs down. What we ran into was the designs had converged to the point that there was no new knowledge in the designs. We had got to the point that we weren't learning very much more about the designs, and in fact, because of the competitive enviroment, we couldn't even discuss things with our contractor team.

There are only so many rocket scientists in this country, and they exist in a couple of big companies and NASA, so we wanted to get the team formed as soon as possible to help us work through all of the final design to get us to the preliminary design review which doesn't occur until 2008. So we wanted to get the contractor team on board in order to do that. Now, if we kept one contractor on and didn't award them the contract to go past the preliminary design review, then I would have been negotiating a contract in a noncompetitive environment, which I don't believe would have been in the best interest of the government. So those are the factors in our strategy of whom we approached this problem.

Mr. UDALL. Are you in a position to answer further, perhaps for the record, my questions about a quantitative estimate of the size and the delay and the cost estimates that might be a part of it?

Dr. HOROWITZ. Sir, I don't have the exact—I can take that for the record and get back to you——

[The information follows:]

In May 2005, the Exploration Systems Architecture Study (ESAS) was initiated with one of its tasks to provide a complete assessment of the top-level Orion CEV requirements. As a result of ESAS, the architecture and the top level requirements for the Orion CEV were chosen, and made part of the Phase 2 competition. At that point, NASA saw no benefit of keeping two prime contractors through Preliminary Design Review (PDR) at an estimated cost of $1 billion each (as in a spiral approach). Rather, NASA saw a better return of its investment in competitively issuing two Phase 1 Orion CEV Prime Contracts for conceptual design and trade studies against the ESAS architecture for an estimated cost of $46 million each.

Mr. UDALL. You will take that for the record.

Mr. LI. Mr. Udall, when we, specifically, asked NASA to be able to quantify that, they told us that they did not do that analysis; so therefore, I do not feel confident that they could have made that particular assertion.

Mr. UDALL. Do you think we ought to ask them to make that assertion?

Mr. LI. Well, I think it is water over the dam at this point in time, but my point is that in order to make an assertion of delays and of extra costs, those should come from analysis, and I don't believe that that analysis was done.

Mr. UDALL. Perhaps the Committee ought to take that under review ourselves, and we may want to ask that NASA actually complete those analyses for us, but that is another day, another story at some point.

Dr. HOROWITZ. Yes, sir.

Mr. UDALL. If I could, just for the record—I see my time is about to expire, and I could get another from Mr. Akin, perhaps—but I am curious why you decided to fundamentally change your acquisition approach, that is, for the CEV after doing a spiral development approach for the first year-and-a-half. And what was wrong with the original acquisition approach?

[The information follows:]

NASA changed its acquisition approach from the previous "spiral development" approach to reduce technical, cost, and schedule risk. Spiral development is a process to achieve a desired capability where the end-state requirements are not known at program initiation. Spiral development was based on an undefined transportation architecture. Subsequent comprehensive requirements definition and independent assessments defined an architecture and showed that a continued spiral approach would no longer fit, as it would increase cost, schedule, and technical risk. NASA made a decision to spend its resources in developing its exploration transportation end-state requirements and architecture for Exploration through a number of parallel efforts for the formulation phase of the Orion Crew Exploration Vehicle (CEV) project. The *NASA Authorization Act of 2005* (P.L. 109–155) also directed NASA to pursue a Shuttle-derived transportation system to support a sustained human presence on the Moon and ability to support future destinations. This approach was also the one chosen through doing trade studies.

In May 2005, the Exploration Systems Architecture Study (ESAS) was initiated with one of its tasks to provide a complete assessment of the top-level Orion CEV requirements. As a result of ESAS, the architecture and the top level requirements for the Orion CEV were chosen, and made part of the Phase 2 competition. At that point, NASA saw no benefit of keeping two prime contractors through Preliminary Design Review (PDR) at an estimated cost of $1 billion each (as in a spiral approach). Rather, NASA saw a better return of its investment in competitively issuing two Phase 1 Orion CEV Prime Contracts for conceptual design and trade studies against the ESAS architecture for an estimated cost of $46 million each.

Additionally, NASA established an intra-agency Orion CEV Smart Buyer team which performed trade studies and design analysis that was used by the Orion CEV Project Office to understand and verify the appropriateness of the requirements incorporated into the Orion CEV Phase 2 solicitation and evaluation of proposals. With knowledge gained from ESAS, the Smart Buyer team, and Orion CEV Phase 1 contracts, NASA was in a position to "down select" to a single Prime contractor and initiate the Design, Development, and Test and Evaluation (DDT&E) contract for the Orion CEV in order to baseline an industry approach and commitment to meet the desired outcomes of the Orion CEV project. This new acquisition approach provides NASA with the capability to shorten the gap in human space flight capability with the retirement of the Space Shuttle in 2010. The original "spiral development" acquisition approach contained significant risk that this nation would not have a human space flight capability by 2014 with a higher development cost of close to $1 billion.

And maybe, Mr. Li, you could comment later for the record as well. Do you have any view regarding the relative merits of those two approaches? And when I say for the record, I don't know if maybe the Chairman wants to cut me off and you could do it writing later or whether he is willing to have you do it here, now.

Dr. HOROWITZ. Certainly.

MORE ON INTEGRATION CHALLENGES

Mr. CALVERT. I thank the gentleman. Also, just for the record, Dr. Horowitz, the capsule, itself, would that capsule be capable to have interaction with the Space Station if necessary?

Dr. HOROWITZ. Yes, sir, absolutely. The capsule can dock with vehicle that has a compatible docking station, so it can go to the Space Station.

Mr. CALVERT. Let us talk about what the long pole on the tent is in this whole program. You know, moving this thing along, even though we are using existing technology, obviously, it is a complex engineering problem. If you had to take one element to this that you consider the long pole in the ten, what would it be?

Dr. HOROWITZ. Sir, right now, the long pole the critical path, would be the J–2X engine on the second stage; it is leading the pack.

Mr. CALVERT. And why is that the case?

Dr. HOROWITZ. The J–2X engine, while the engine is a derivate of the J–2 that flew in the Apollo mission, we have to redo the tooling and the manufacturing and bring the engine up to today's standards. The lead time for components, for example, valves, if you want to order just abilitative metal to make these cryogenic valves, there is at least a three-year lead time on some of those components, so the development and the amount of testing to get it to our standards make that engine unavailable until 2012.

Mr. CALVERT. Is there any way that that can work out any quicker than the 2012 timeline or is that a conservative estimate?

Dr. HOROWITZ. Well, sir, we will have engines in the test stand before 2012, but just because of the amount of testing and the lead time on articles, you could put a lot of money in and accelerate the program a few months, but there is no way to accelerate that engine, say, one or two years earlier just because of the lead time required and the testing required to get it up to the standards we want.

Mr. CALVERT. Mr. Li, what would you identify from your perspective?

Mr. LI. From my perspective, obviously, Dr. Horowitz has a lot more of the technical knowledge of the design. You know, NASA is designing them. From my perspective, from a management perspective, I am the most worried about them succumbing to, perhaps, of both money and time, and maybe bypassing and short-changing what I would consider to be some basic, sound systems engineering practicing, and that is making sure that you do the testing, making sure that there are certain reviews that are done.

In preparation for this hearing, I was going through some of my old papers of some of the things that have occurred at NASA, and I recollect things such as the unfortunate occurrence with Mars Polar Lander where, in that particular case, where because of the desire to cut costs, they did not do a full-up test, and as a result, there are some issues associated with spurious signals that made the spacecraft think that it was closer than what it was and it crashed. I think that that is, to me, the thing that I worry about the most, is allowing those pressures to make one to make some decision from a systems-engineering perspective and short-change them.

MORE ON INTERNATIONAL COMPETITION

Mr. CALVERT. And we hope that that would not occur, but on one hand, if I look back on history, back when John F. Kennedy first made his speech that we will go to the Moon, and from the time that we had that speech to the time that we went to the Moon, it was probably less time than we are talking about between now and the launch in 2014, and this was something that was done a long time ago. Many people in the audience weren't even alive at the time. And in this country, some comments I hear when I go around the country, been there, done that. Why are we doing it again? And it is interesting that we forgot how. We cannot do that today. We do not have the technology today to do that kind of endeavor, and now we are striving to move back forward again. And unlike 1969, we are looking in the rearview mirror, and we have other people right on our tailpipe, using the car analogy again. Mr. Rohrabacher?

Mr. ROHRABACHER. Well, I think that in 1969, if you remember, we did have a race with the Russians at that time, and we were looking in the rearview mirror. And luckily for the Chinese, we have——

Mr. CALVERT. They weren't going to the Moon, though.

Mr. ROHRABACHER. And luckily for the Chinese, we have diverted enough technology to them over the last ten years in order to provide them excellent missile and rocket and technology so they are in our rearview mirror. Let us make sure, I would hope, as our NASA director visits the Chinese—as he is, I believe, right now, as I speak—I hope that he remember the last time we tried to cooperate with the Chinese. It wasn't to our benefit. In terms—I reminded Mr. Ehlers that the X–33 program that he was talking about that Mr. Horowitz and I talked about in my office the other day, that program spent, I think, $1 billion-and-a-half dollars, and that was, interestingly enough, being built by the same company that has been given the contract for this project. Let us hope that that is not repeated, and we are going to watch that very closely.

MORE CEV BUDGET CONCERNS

I agree with Mr. Ehlers that, certainly, robotics is a cheaper method than building things that are capable of human space flight. But I understand, Mr. Horowitz, and you may correct me if I am wrong, that this overall project will include the use of robotics, and is designed to actually use robotics to facilitate some of the missions that we are going to then end up putting men, or should I say human beings, after the robots have led the way. That, itself, is, I am sure, cost-saving a certain amount of money because of the expense of taking care of contingencies.

I want to compliment NASA and Mike Griffin for the concept of using technology that is already tested and proven for significant parts of this new project, because as you say, that in it self has saved an enormous amount of money and time because you know there are large numbers of parts of these projects that work because they have already worked. Integrating them has not been tested yet, and that is part of it.

So I think Mr. Chairman, we should be recognizing this strenuous effort to try to us that as a means of keeping down costs. But still, with all of that said, the cost does seem to be rather high, so I do not understand why it costs so much, especially if you have so many parts that have been already used and tested, why it costs $31 billion to get to the point where we are going to have one of those rockets. Thirty-one billion dollars is a lot of money, and here, just to get to that point, to get that rocket launched, it is $31 billion, is it not? That is as of today. That is if all of Mr. Li's fears don't come true, and the costs don't go up after that.

Dr. HOROWITZ. Sir, if you like, I will take that question, and the $31 billion number that you mentioned in the integrated cost for all of exploration through our budget run-out. That includes all of the robotics——

Mr. ROHRABACHER. Okay, but that is not just that——

Dr. HOROWITZ. That is not just this, sir——

Mr. ROHRABACHER. I am glad I asked that question.

Dr. HOROWITZ. I am sorry.

Mr. ROHRABACHER. How much is it just for that rocket?

Dr. HOROWITZ. Well, I can, like I said, I will take that for the record. I can get you a breakdown of every component that we have and the cost estimation of every single component and where the money is being spent.

Mr. ROHRABACHER. No, I just want to know basically. I don't need every component.

Dr. HOROWITZ. Right.

[The information follows:]

Launch vehicle costs for the Ares I Crew Launch Vehicle through the first human launch, currently projected late in FY 2014, are approximately $10.8 billion. This number excludes the Orion Crew Exploration Vehicle, mission and ground operations and facility modifications, and program integration and other program-level costs. Orion Crew Exploration Vehicle project costs through first human flight are about $10.3 billion. Therefore, combined Ares I and Orion project costs through first human launch are about $21.1 billion. If related required programmatic and non-flight hardware costs are included in the estimate, it will cost about $33.5 billion to get to the point of first human launch projected in 2014.

All of these numbers include reserves, but exclude Corporate G&A. These numbers include estimates for FYs 2012, 2013, and 2014, which lie beyond the budget horizon.

Mr. ROHRABACHER. When that rocket is launched, I want to know how much it is going to cost to get us from here to there. Is it $5 billion? Is it $10? I am glad you just straightened out the $31 billion number for me. That is what these hearings are all about.

Dr. HOROWITZ. Yes, sir. And we will break it down any way you like. If you would like just the integrated stack, I can get you that cost or the launch cost to launch it or the total infrastructure.

Mr. ROHRABACHER. When we launch that first rocket, how much does it cost? That is what we want to know, how are we going to get from here to there. That will be very helpful.

Dr. HOROWITZ. I will be more than happy to bring those numbers to you.

MORE INTEGRATION CHALLENGES

Mr. ROHRABACHER. Well, thank you very much, and I want to thank Chairman Boehlert, and of course, Chairman Calvert for their leadership, and I am looking forward to working with you and following this project to make sure—Remember this: we are facing $3 billion right down the toilet because they based it on that system and taking, building, spending the money before they had a piece of technology that worked, and then it never did work. And you are telling us that that is not going to happen in this program because everything works. Is that right?

Dr. HOROWITZ. Yes, sir.

Mr. ROHRABACHER. Okay, is that your reading, Mr. Li?

Mr. LI. I still think I disagree somewhat, and I still think there are some technologies that are being developed. The landing system, it is my understanding, is still something that has not reached the technology readiness level that they would like at this point in time, so I still think there is some issue there.

Mr. ROHRABACHER. So you have got some worries. We are going to follow this. Thank you very much, Mr. Chairman.

Mr. CALVERT. I thank the gentleman. Mr. Udall, do you have any additional questions?

MORE BUDGET CONCERNS

Mr. UDALL. I don't know if you want to give me a third chance here, Mr. Chairman.

One question, for the record, Mr. Li. I know we have talked quite a bit about whether you are being too conservative and not adequately accounting for the CEV and the CLV program's use of existing technology in their designs, which NASA says considerably reduces the risk. But what you know now of NASA's approach, do you accept NASA's assessment of these risks, and if now, why not. And I know you have talked of this quite a bit during the hearing, but if I could get it on the record.

Mr. LI. Well, again, I understand that there are a lot of components that have been used before. But as NASA will say themselves, we are talking about new processes. It is new technology. It would be foolish to take technology that was used on the Apollo and put it in this particular vehicle. We are talking about smaller things that probably do the same things; but however, when you shrink things into a smaller size, that is when you run the risk of having some problems. So yes, I understand functionally that there are some things that we have proven when you bring it down to form, fit and function, that is when I worry.

Mr. UDALL. Thank you. If you have other thoughts as the weeks unfold, we would appreciate any additional comments in the record. Again, thanks to the witnesses.

Mr. CALVERT. Well, if we have no further questions, we are——

Mr. ROHRABACHER. Could I add one thing for the record, Mr. Chairman? And that is Mr. Li, over the years, has been a tremendous source of information and guidance for this, and we thank you very much, Mr. Li, for that.

Mr. CALVERT. We thank you for your service. Thank you very much. We are adjourned.

[Whereupon, at 3:53 p.m., the Committee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Scott J. Horowitz, Associate Administrator, Exploration Systems Mission Directorate, National Aeronautics and Space Administration (NASA)

Questions submitted by Chairman Sherwood L. Boehlert

Q1. During your testimony, you identified "systems integration" as a difficult part of Orion and Ares development. Are there particular areas that you can already identify as potentially problematic? Where might problems arise and when might those become apparent?

A1. NASA recognizes that systems integration will be critical to the success of Orion and Ares development. To help deal with the challenge, the Orion and Ares projects are structured based upon the formal NASA Procedural Requirements (NPR) of NPR 7120.5 (Program and Project Management Processes and Requirements) and NPR 7123.1 (Systems Engineering Procedural Requirements). These Agency technical procedures provide best practice guidance, including systems engineering, for all programs and projects to adhere to. NPR 7123 requires each program to maintain an approved System Engineering Management Plan (SEMP) to control the life cycle technical management process. The Constellation Program SEMP establishes the approaches for integrating and organizing People, Products/ Orion/Ares, and Processes for successfully achieving the requirements.

There are no known problematic systems engineering areas at this time. The Constellation Program has established and is executing a rigorous Risk Management process to identify, control, and mitigate risks at the earliest time possible. This Risk Management process is being used effectively by the Program on Orion and Ares development and integration efforts in the areas such as design, analysis, requirements, test & verification (T&V), and manufacturing. This Risk Management process identified two early development risks: performance of the integrated Launch Abort System and Command Module, and performance of the integrated CEV and CLV during ascent. These risk concerns are expected to decrease over time because they were identified early, and risk mitigation plans will be implemented to reduce these risks.

Systems integration for a program of this caliber is challenging. To counter and manage any unexpected integration related challenges, the program is using the formal processes and procedures required by NPR 7120.5 and NPR 7123. As such, a challenge could become apparent during vigorous T&V, which is being designed by the Program to capture and resolve any unexpected development or integration related challenges at the earliest. For example, the Flight Test Strategy calls for early T&V of progressively mature test article configurations leading to the first planned flight test in 2009. Any challenges that arise during the T&V will be resolved before they become apparent risks to the overall success of Orion, Ares and the Constellation program.

Q2. What are the most likely additional design changes that could be made to Orion in the future, and could they be absorbed in current budget estimates?

A2. Orion is currently in the formulation stage of the project. The specific details of the design will continue to mature until the design is finalized at the Critical Design Review (CDR). However, a number of major design areas have already been established, and, therefore, budget risk of future changes is low. Consequently, notwithstanding the maturity of the design, NASA currently believes that it has the budget to develop Orion.

Q3. How many technology and cost threats are currently being carried by Orion? The Ares I upper-stage? The Ares I first stage? NASA's notification to Congress on its intent to begin development of Orion states that NASA has identified no "areas in the CEV [Crew Exploration Vehicle] concept where the technology is immature." Would you assess the Ares vehicle similarly? Does this assessment suggest that the current technology and cost risks are very unlikely to occur?

A3. The Ares I has minimal technology development activities due to the extensive use of heritage hardware. However, there are certain components of the Upper Stage that may require advanced development, such as the Reaction Control System (RCS) thrusters, Thrust Vector Control (TVC) systems, and various main propulsion system (MPS) components. All are within acceptable technology readiness levels to be inserted into the project without risk.

Cost threats associated with Ares I exist due to the transition between the Shuttle Program close-out and Constellation Program ramp-up. Although synergy between the Shuttle program and Ares I helps the transition, it also presents a challenge. Budgets and schedules tend to be contingent on each other. The challenge comes as Orion ramps up and Shuttle is still operating at full strength in support of missions to ISS. Even with the best of transition planning, there may be issues related to Shuttle program close-out activities that may impact Ares I development activities.

The Orion vehicle relies on proven technologies for its design implementation. However, there are two areas where NASA felt that it was appropriate to begin early advanced development work prior to the award of the Prime contract. These areas are the Thermal Protection System and the Landing System. As a part of this development work, NASA has performed analysis and testing on materials and subsystem components for these two systems.

Orion is subject to the cost risks associated with the normal unknowns of any development project. However, NASA has put management tools in place to identify and address those risks.

Q4. How many "end item" milestone awards are included in each schedule of the Orion contract and what is the approximate value of those awards?

A4. The base contract contains nine milestone periods where the contractor may receive award fee payments. The maximum fee available varies, depending on the milestone, and generally the later milestones have larger fee amounts. The first evaluation period ends at the Systems Design Review (SDR), and the maximum fee amount for this period is $19,438,745. The largest maximum fee amount is $149,515,277 for the period ending with the delivery of the first flight vehicle. [It should be noted that all fee's considered a provisional payment. The final award fee amount will be made based on the contractor's performance over the entire period of performance.]

An "End Item" award fee contract is being used in the Orion contract in order to measure the true quality of contractor performance at the end of the contract. Therefore, the total contract award fee pool is available and the contractor's total performance is evaluated against the award fee plan to determine total earned award fee. In addition to the final evaluation, interim evaluations are done to monitor performance prior to contract completion in order to provide feedback to the contractor on the Government's assessment of the quality of the contractor's performance, and to establish the basis for making interim award fee payments. These interim award fee assessments are done at key milestone periods in the contract. Therefore all fee paid during the contract are considered interim payments. A final award fee determination will be made, based on the contractor's performance over the entire contract, which will determine the award fee amount earned by the contractor for the contract.

Q5. Given that the Ares I is also in the very early stages of development, how can NASA be confident that the rocket will perform well enough to support the current design of Orion? In your testimony, you said that the program carried roughly 25 percent margin, combining the vehicle performance and payload mass margins for a lunar mission. Specifically, you said:

> *The launch vehicle itself has margins, so we will ask the vehicle to lift, say 50,000 pounds to a certain orbit. The project manager for the launch vehicle is keeping performance margin for his launch vehicle, so the vehicle may be able to lift 55,000 pounds, and his margin is on the order of about 15 percent or so for the launch vehicle. We also have margin that the CEV project manager has to hold on his side in case his vehicle gets larger, also. The integrated margin, right now, for the total moon mission, not just the low-Earth orbit. We have huge margins to get to low-Earth orbit. But to be able to carry up to the lunar mission, approaching 2020 at this point, we have about 25 percent performance margin on the amount of lift this vehicle can provide.*

What is the individual margin for Ares performance and Orion mass for a lunar mission? Furthermore, what is the current level of performance margin for Ares I to deliver Orion to an orbit equivalent to that of the International Space Station? What mass margin is currently held by Orion for an ISS rendezvous mission? How do these margins compare to margins held by previous launch vehicle designs?

A5. Performance margin is the usable performance capability reserved to protect mission injection conditions. The Ares I design team is using validated engineering tools that are used to set the allocations to the elements for initial planning. These tools are anchored in historical 'as flown' capabilities and tend to envelope loads and weights. The Ares I Project currently has 15 percent margin reserved for uncertainties in nominal vehicle parameters or their dispersions and this margin is used to protect vehicle capability requirements for modifications or a new design. This margin will be maintained to minimize the risk of failure to deliver Orion to its required orbit, either ISS or for a lunar mission.

The Orion project uses a historically based "schedule" to determine weight growth allowances for each subsystem. The weight growth allowance will vary depending on the historical risk of weight growth for each type of subsystem. The allowable weight growth will also reduce over time as the design matures. For the lunar mission Orion is carrying approximately 15 percent weight growth allowance. In addition, Orion has allocated another 10 percent margin that is carried as reserve. For Orion the lunar case is the most challenging from a weight growth perspective. Therefore, the margins for a potential mission to the Space Station are lower than those listed above for the lunar mission.

Q6. In a letter responding to §102 of the NASA Authorization Act of 2005, *NASA stated that "a higher than expected CEV cost would simply delay CEV development or production. . ." Given that Orion and Ares I currently consume the bulk of Exploration funding and the current schedule supports operations no earlier than 2014, can NASA implement its go-as-you-can-afford-to-pay philosophy for the program while meeting the President's deadline of a 2014 launch?*

A6. At its early formulation stage, the Constellation Program is certain to face "unknown unknowns" as we continue to refine requirements, develop advanced technologies, and begin to integrate the various systems into an operational infrastructure to enable long-term exploration of the Moon and Mars. When Constellation moves into the implementation phase, after Preliminary Design Review, currently scheduled for the spring of 2008, design, cost, and schedule baselines will be established, and Program performance will be measured against metrics established at the various key decision points throughout the life of the mission. It is at this juncture that NASA will provide Constellation project Life Cycle Cost commitments to Congress.

Yet even before these baselines are established, the Constellation Program is operating under a "go-as-you-can-afford-to-pay" constraint; we are living within a set budget profile, and any growth beyond our capacity to perform trades, de-scope, or apply reserve will result in a slip to the baseline schedule. We are making every effort to avoid this through aggressive use of management tools at all phases of the Program: defining and controlling requirements, generating realistic cost estimates early on (ESAS), employing a "smart buyer" approach to major acquisitions, and monitoring performance by means of a rigorous earned value system. Thus far, we have been successful in achieving critical milestones within our budget profile.

Q7. When would a decision to exercise Options B and C need to be made to support operations in 2014 and beyond? At the time NASA decides to exercise these options, will the Ares I launch vehicle have completed Preliminary Design Review? Will the Ares I have completed Critical Design Review?

A7. The Orion CEV flight units necessary for the first human launch and the first cargo launch are developed under Schedule A. The current contract states that Options B & C need to be exercised no later than July 2009. The Orion PDR is currently scheduled for March 2008 and the CDR is currently scheduled for April 2009. The Ares I PDR is currently scheduled for April 2008 with CDR currently scheduled for September 2009.

Q8. Has the Agency or its contractors identified the activities needed to support PDR? What post-PDR activities are currently being pursued by NASA or its contractors? What is the cost of these activities?

A8. The Orion PDR is currently scheduled for April 2008. The costs of PDR will include all expenses prior to this date—approximately $5.5 billion. In a major development program, approximately 15 percent of programmatic dollars would be consumed by PDR. A successful PDR will require completed design specifications, the identification and acquisition of long-lead items, manufacturing plans, and firm life cycle cost estimates, a methodical process that effectively brings the design to 30 percent completion. The PDR will provide the basis for determining whether the baseline design is acceptable and if the process leading to Critical Design Review may proceed.

Questions submitted by Representative Bart Gordon

Q1. In the letter from Deputy Administrator Dale that non-concurred with GAO's report, she stated that as part of the CEV contract competition that was just com-

pleted: "NASA will receive firm competitive prices from industry to complete development of the CEV. . .NASA will also establish not-to-exceed prices for production of required CEVs to support the current flight manifest through 2019."

Q1a. Given NASA's stated confidence in having firm pricing data, is NASA willing to accept a formal cost cap on the CEV program? If so, at what level would NASA propose the cost cap be set?

Q1b. If not now, at what point in the CEV development program would NASA be willing to accept a formal cost cap?

A1a, 1b. Historically, cost caps have not proven effective in managing major NASA research and development (R&D) programs. Constraining the International Space Station (ISS) to $2.1 billion annually did little to control overall program costs. And while life cycle cost caps are regularly imposed on small, discrete projects (e.g., Explorer, Discovery) as part of the selection process, they are not easily adapted to major R&D efforts that extend far beyond the current budget horizon. In the case of large development programs such as Constellation, cost caps can be problematic as they depend on assumptions regarding outyear funding. The future priorities of the country are not known and can change over the life of the Constellation program.

At its early formulation stage, the Constellation Program is certain to face "unknown unknowns" as we continue to refine requirements, develop advanced technologies, and begin to integrate the various systems into an operational infrastructure to enable long-term exploration of the Moon and Mars. When Constellation moves into the implementation phase, after Preliminary Design Review (PDR) in the spring of 2008, design, cost, and schedule baselines will be established, and Program performance will be measured against metrics established at the various key decision points throughout the life of the program. At this juncture, NASA will submit Constellation project life cycle cost commitments to Congress. Under Section 103 of the *NASA Authorization Act of 2005* (P.L. 109–155), NASA is required to submit Major Program Annual Reports, the first of which shall include a Baseline Report that is to include an estimate of the life cycle cost for those programs. Under Section 103, NASA is required to report changes to the Baseline Report—including life cycle cost estimates—as part of the annual budget request. NASA will notify the Committee at other junctures, as necessary, if there are any adjustments to life cycle cost estimates. As such, NASA would advise against imposition of a formal statutory "cost cap" on CEV development.

Q2a. In your testimony, you stated that you have only three things you can vary in the CEV program: cost, schedule, and performance. If there is cost growth in the CEV program, what specifically will be your approach to dealing with it?

What changes in performance or program content would be feasible to make in order to contain cost growth?

A2a. NASA is committed to the "go-as-you-can-afford-to-pay" approach. In this approach, the implementation of capabilities can be delayed until the budget is available. For example, the Orion CEV is being designed as a vehicle for the lunar mission, and development of some capabilities for that mission can be delayed until needed. For example, the Guidance, Navigation, and Control GN&C software required to get to lunar orbit and return is not necessary for the CEV's early flights.

Q2b. Is there a date beyond which you would not slip the CEV schedule? If so, what is it?

A2b. The *NASA Authorization Act of 2005* (P.L. 109–155) endorses the President's *Vision for Space Exploration,* which charged NASA to conduct the first manned mission no later than 2014.

Q2c. Is it possible to slip CEV schedule without increasing the life cycle cost of the CEV program? If so, how?

A2c. Experience has shown that, if the completion of elements of major development programs is delayed significantly, the overall cost of a major development program will go up.

*Q3a. The GAO has pointed out that with respect to your budget plan, ". . .*there are years when NASA does not have sufficient funding to implement the architecture. Some yearly shortfalls exceed $1 billion, while in other years the funding available exceeds needed resources." *In fact, NASA is proposing to "bank" funds in its CEV and CLV account in FY 2006 and FY 2007 in excess of what it could spend in those years, with the intent of trying to make those funds* *available in later years when its planned funding is insufficient to meet the program's needs.*

Why, only two years into the President's multi-decade Vision for Space Exploration *(VSE), is NASA having to resort to such budgetary maneuvers to fund its implementation of the Exploration initiative?*

A3a. The President called for an affordable and sustainable program of exploration. Reflecting that direction, our budget profile is relatively level, though the natural funding curve for a major development program, such as Constellation, is not flat. When NASA retires the Space Shuttle, additional funds will become available for Constellation, but that will not occur until 2010. Long-lead procurements and early design effort will ramp up prior to 2010. Therefore, as NASA has outlined for the Committee in correspondence and testimony, funding carryover for Constellation will allow us to meet those requirements in FY 2008 and FY 2009.

Q3b. Why shouldn't Congress insist that NASA only submit requests for funding that are consistent with the actual Exploration program funding needs in a given fiscal year—especially given the competing demands for funds in other parts of NASA? Wouldn't such an approach be more aligned to the way development programs historically have been funded?

A3b. One of the ways the ups and downs of development funding curves can be accommodated is by optimizing the use of two-year R&D funding, and phasing the program schedule to align with available funding.

Q4. Why was it necessary to shift almost $7 billion into the Constellation program [which includes the CEV and CLV] for the years FY 2006 to FY 2010 compared to what NASA had said would be needed over that period in last year's budget request?

Q4a. Did NASA underestimate the cost of the CEV and CLV programs?

Q4b. NASA has indicated that it will not be possible to launch an operational *CEV until 2014—which was the original goal—despite the additional funds that have been transferred into the program to "accelerate" it. Why is that?*

A4a, 4b. NASA did not underestimate the life cycle costs. Funding for Constellation Systems has been increased from the FY 2006 President's Budget within overall Exploration Systems Mission Directorate funding. This budget increase reflects the Agency's position, based on the results of the ESAS, the President's continuing commitment to the priorities identified in the *Vision for Space Exploration,* and the *NASA Authorization Act of 2005* (P.L. 109–155). Increased funds are specifically identified for the Orion CEV and Ares I CLV in order to ensure their ability to launch humans no later than 2014, but as close to 2010 as possible.

Increased funding for the CEV supported a better defined, lower-risk program with an earlier down-select to a single contractor for CEV design; a Preliminary Design Review in FY 2008; Critical Design Review in FY 2009; potential design verification tests in 2007 (to be determined after selection of a prime contractor); and initial tests of a Launch Abort System starting in FY 2009 (or sooner, depending on available funding).

Increased funding for the Ares I CLV supports early design work with Space Shuttle contractors to prepare the solid rocket boosters for use as the first stage of the Ares I CLV; development of a propulsion system for the upper stage of the Ares I CLV; and early design work to modify the Space Shuttle main engine (SSME) for use as an expendable engine on the future Ares V Cargo Launch Vehicle (CaLV).

A plan was put in place early in 2006 to effectively accelerate development activities by refocusing on developing Ares I hardware with greater extensibility to the Ares V system. Consistent with this new strategy, NASA made several launch vehicle architectural design adjustments such as changing the four-segment RSRM first stage to a five-segment RSRM first stage, and replacing the SSME upper stage engine with the J–2S-derived J–2X engine. These architectural changes reduced the number of distinct development cycles by capitalizing on design synergies between the Ares I and the Ares V: single upper stage development (J–2X) and increased first stage commonality between Ares I and Ares V. This will, in turn, reduce life cycle costs and major risks.

Funding is also necessary to support initial design efforts to modify, or in some cases start from new, necessary ground systems to support the operational requirements of the Ares I and Ares V. This includes potential changes to the launch infrastructure at Kennedy Space Center, as well as NASA's ground-based and in-space communications infrastructure for space exploration missions.

Question submitted by Representative Ralph M. Hall

Q1. What is the cost estimate for the major components of Orion: the Launch Abort System, Crew Module, Service Module, and inter-stage?

A1. NASA does not currently track Orion CEV costs in a way that allows the determination of the cost of the Launch Abort System and other components. NASA is currently working with the Orion Prime Contractor on a contract modification that will, among other things, modify the Work Breakdown Structure (WBS) to allow collection of costs by Service Module, Crew Module and Launch Abort System. This work will be complete in the early spring 2007 to support the activities for the FY 2009 budget cycle.

Question submitted by Representative Dana Rohrabacher

Q1. Please provide NASA's estimate for the total cost of the Orion and Ares I development programs through the test flights of Orion.

A1. Launch vehicle costs for the Ares I Crew Launch Vehicle through the first human launch, currently projected late in FY 2014, are approximately $10.8 billion. This number excludes the Orion Crew Exploration Vehicle, mission and ground operations and facility modifications, and program integration and other program-level costs. Orion Crew Exploration Vehicle project costs through first human flight are about $10.3 billion. Therefore, combined Ares I and Orion project costs through first human launch are about $21.1 billion. If related required programmatic and non-flight hardware costs are included in the estimate, it will cost about $33.5 billion to get to the point of first human launch projected in 2014.

All of these numbers include reserves, but exclude Corporate G&A. These numbers include estimates for FYs 2012, 2013, and 2014, which lie beyond the budget horizon.

Questions submitted by Representative Jo Bonner

Q1. Recent Shuttle missions have shown the importance of having a robotic arm and cameras to properly inspect the Shuttle. Do you feel a robotic arm might be beneficial when inspecting the CEV, either when it's not attached to the International Space Station, in a another orbit, or on a separate mission? Do you believe a robotic arm would be beneficial for future space missions?

A1. The Orion vehicle is designed to be inherently safer than the Shuttle in that the heat shield used to protect the capsule during re-entry is protected from launch and on-orbit debris by Service Module for most of the mission. Just prior to the Crew Module return to Earth, the Service Module is jettisoned and this exposes the heat shield. The heat shield is designed to be replaced after each mission. Based on this improved overall technical concept of operation, the Orion does not include a robotic arm.

Q2. Is there a robotic arm currently being considered on the CEV, and if so, is it included in the draft drawings of the CEV?

A2. The current Orion design concept does not include a robotic arm.

Questions submitted by Representative Mark Udall

Q1. Why did NASA decide to fundamentally change its acquisition approach for the CEV after pursuing a "spiral development" approach for the first one and a half years of the Exploration initiative? What was wrong with the original acquisition approach?

A1. NASA changed its acquisition approach from the previous "spiral development" approach to reduce technical, cost, and schedule risk. Spiral development is a process to achieve a desired capability where the end-state requirements are not known at program initiation. Spiral development was based on an undefined transportation architecture. Subsequent comprehensive requirements definition and independent assessments defined an architecture and showed that a continued spiral approach would no longer fit, as it would increase cost, schedule, and technical risk. NASA made a decision to spend its resources in developing its exploration transportation end-state requirements and architecture for Exploration through a number of parallel efforts for the formulation phase of the Orion Crew Exploration Vehicle (CEV) project. The *NASA Authorization Act of 2005* (P.L. 109–155) also directed NASA to pursue a Shuttle-derived transportation system to support a sustained human presence on the Moon and ability to support future destinations. This approach was also the one chosen through doing trade studies.

In May 2005, the Exploration Systems Architecture Study (ESAS) was initiated with one of its tasks to provide a complete assessment of the top-level Orion CEV requirements. As a result of ESAS, the architecture and the top level requirements for the Orion CEV were chosen, and made part of the Phase 2 competition. At that point, NASA saw no benefit of keeping two prime contractors through Preliminary Design Review (PDR) at an estimated cost of $1 billion each (as in a spiral approach). Rather, NASA saw a better return of its investment in competitively issuing two Phase 1 Orion CEV Prime Contracts for conceptual design and trade studies against the ESAS architecture for an estimated cost of $46 million each.

Additionally, NASA established an intra-agency Orion CEV Smart Buyer team which performed trade studies and design analysis that was used by the Orion CEV Project Office to understand and verify the appropriateness of the requirements incorporated into the Orion CEV Phase 2 solicitation and evaluation of proposals. With knowledge gained from ESAS, the Smart Buyer team, and Orion CEV Phase 1 contracts, NASA was in a position to “down select” to a single Prime contractor and initiate the Design, Development, and Test and Evaluation (DDT&E) contract for the Orion CEV in order to baseline an industry approach and commitment to meet the desired outcomes of the Orion CEV project. This new acquisition approach provides NASA with the capability to shorten the gap in human space flight capability with the retirement of the Space Shuttle in 2010. The original “spiral development” acquisition approach contained significant risk that this nation would not have a human space flight capability by 2014 with a higher development cost of close to $1 billion.

Q2. In order to make your proposed CEV and CLV acquisition approaches work, NASA has had to shift significant amounts of funding from the exploration technology R&D and Space Station research accounts. Do you intend to restore all of the funding that was cut from those accounts? If so, when will that occur?

A2. Last year, the content of the ESMD Research and Technology Development program was prioritized, (Human Systems Research and Technology (HSRT) and Exploration Systems Research and Technology (ESRT)), as part of the Exploration Systems Architecture Study (ESAS) review, to ensure that the R&T portfolio directly supports requirements of the Constellation Systems program. The Exploration Technology Development content was substantially reduced through this prioritization activity and retains only the high priority research and technology development projects that support exploration needs. Future research and technology development will be phased so that technologies are ready when they are needed to meet the Constellation program development schedules.

Additionally, NASA is conducting research and developing new technologies for lunar and Mars exploration that will reduce mission risk, reduce logistics requirements, and reduce mission life cycle cost. In-situ resource utilization and non-toxic power and propulsion systems are examples of these kinds of technologies. These investments also have important connections to U.S. scientific, economic, and national security interests.

Q3. If Congress followed GAO’s recommendation to restrict annual appropriations and limit obligations for the CEV project “to only the amount of funding necessary to support activities needed to successfully complete the project’s preliminary design review,”

Q3a. What impact would that have on NASA’s schedule for developing and deploying the CEV, including the impact on procurement of long-lead items? What is your estimate based on?

Q3b. What impact would that have on NASA’s cost to develop and deploy the CEV? What is your estimate based on?

A3a, 3b. The impact of restricting appropriations for CEV to only support PDR, currently scheduled for April 2008, would be very negative. The Orion CEV benefits from a competitive down select process in which NASA received an innovative cost, technical, and management approach from Lockheed Martin. This effort relies upon continuity within the Development and Test phase of the Orion CEV contract. The PDR is a part of the engineering development process and not an end item for the development of the Orion CEV.

The line between preliminary design and detailed design is a blurry one. PDR is a somewhat arbitrary construct that permits the customer to make a detailed assessment of progress to date, set at the time when most of the preliminary design is complete. Some will have been completed long ago, and, typically, some items will not be complete at PDR. DDT&E for differing phases of development is not set forth in a serial, end-to-beginning fashion. Rather, an efficient plan has different phases beginning and ending at different times for different components and subsystems. Using the PDR as a hard break in the activities of the prime contractor would prevent Orion CEV from being developed as efficiently as possible, and would affect cost and schedule accordingly.

The delay in execution of a comprehensive development plan by industry would also cause a delay in the completion of that plan. This would add time to the schedule, and experience shows that extending the development schedule is one of the primary causes of increased costs to a development program. The ideal situation is to allow a contractor to make an efficient and effective plan through completion of development, and to reduce perturbations to that plan to an absolute minimum.

In addition, division of DDT&E into two contracts, with the second contract awarded after PDR, would mandate that the second contract be a sole-source negotiation. The alternative to this is to change prime contractors, resulting in significant delay and rework. Under this scenario, negotiations regarding the largest expense of the development effort, the final hardware design and fabrication, would occur without the benefit of competition. Based on long, historical experience with large multi-year contracts, NASA is convinced that this approach would create great cost and/or schedule risk.

Given the knowledge NASA has with regard to its end-state requirements, the most effective end-item to procure at this point is a fully funded DDT&E effort. There is no benefit for the Government to limit the funding and the contract to PDR of the development phase of the Orion CEV project.

Q4. What are the major challenges facing NASA as it moves to implement its Constellation program [which includes both the CEV and its Crew Launch Vehicle (CLV)]?

A4. From a technical perspective, the Ares I CLV has three top technical risks: launch vehicle operability; ability to meet Ares I performance requirements; and, the J–2X development schedule. The Constellation Program is carrying two risks for Orion, the risk of mass growth and the Launch Abort System development. NASA does have risk mitigation activities and plans in place.

Q5. When NASA announced its Exploration architecture last fall, the Crew Launch Vehicle (CLV) was supposed to make use of flight-proven Space Shuttle components. To what extent is that still the case, and for those cases where Shuttle hardware will no longer be used or will be significantly modified, how will CLV costs and programmatic risk be affected? On what is your assessment based?

A5. Ares incorporates Space Shuttle components in addition to utilizing the infrastructure and workforce associated with the Space Shuttle. The human-rated Ares I that will deliver the CEV to low-Earth orbit (LEO) early next decade is an in-line configuration with a five-segment first stage Reusable Solid Rocket Booster (RSRB) based on the Space Shuttle Solid Rocket Booster (SRB).

The heavy-lift Cargo Launch Vehicle (CaLV) also builds on heritage hardware from the Apollo and Space Shuttle vehicles, with a propulsion core consisting of a 33-foot diameter core tank with five expendable RS–68 engines and two modified Ares I First Stage RSRBs.

Hardware commonality between the Ares I CLV and Ares V CaLV, such as the RSRB and the J–2X engine, will reduce the logistics footprint, as well as non-recurring and fixed operations costs, which will help sustain long-term space exploration, expanding humanity's reach to the Moon, Mars, and beyond. Where we are not using Shuttle hardware, we are using heritage J–2 engines used by the Apollo Saturn vehicles and for X–33 testing. We believe by using heritage hardware and having an active risk mitigation plan and approach will reduce life cycle costs and risks.

NASA has spent the past year continuing to refine and mitigate concept risks through the combination of trades and analysis performed by NASA in-house teams. As a result of ESAS and the ensuing work, the architecture and the top-level requirements for the Ares I were established. The Constellation Program systems engineering and integration process has been established to control changes to missions, requirements, cost, schedule and risk as these occur normally through the project formulation and development processes. Monthly Ares I reviews of technical content, cost, schedule, and principle risk factors are performed to integrate and control the risks from each element and determine if these risks and mitigation strategies should be elevated to the top Ares I project risk list and coordinated with the Constellation Program office.

Questions submitted by Representative Eddie Bernice Johnson

Q1. Does NASA have the financial resources necessary to complete the acquisition strategy that it has adopted for the CEV?

A1. At this time based on what we know—yes. In its early formulation stage, the Constellation Program is certain to face "unknown unknowns" as we continue to refine requirements, develop advanced technologies, and begin to integrate the various systems into an operational infrastructure to enable long-term exploration of the Moon and Mars. When Constellation moves into the implementation phase, after Preliminary Design Review in the spring of 2008, design, cost, and schedule baselines will be established, and program performance will be measured against metrics established at the various key decision points throughout the life of the mission. At this point NASA will declare Constellation project Life Cycle Cost commitments to Congress.

We are making every effort to avoid cost growth and schedule slip, through aggressive use of management tools at all phases of the Program: defining and controlling requirements, generating realistic cost estimates early on (ESAS), employing a "smart buyer" approach to major acquisitions, and monitoring performance by means of a rigorous earned value management system. Thus far, we have been successful in achieving critical milestones within our budget profile.

Q1a. What particular aspects of the acquisition activity have the potential for significant cost growth?

A1a. The Constellation Program is carrying two risks for the CEV. The first is a risk common to most development programs and that is the risk that the mass of the system will outgrow its control mass. The other risk carried for CEV is the challenging schedule to develop and test the Launch Abort System. As with any complex system, risks are present and trades option analysis/studies are performed to determine the best approach to mitigate these risks. The study results will provide the best mitigation strategy to buy down each risk.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Allen Li, Director, Acquisition and Sourcing Management, Government Accountability Office

Questions submitted by Chairman Sherwood L. Boehlert

Q1. NASA's notification to Congress on its intent to begin development of Orion states that NASA has identified no "areas in the CEV concept where the technology is immature." What is your view on NASA's assertions that risks on the Orion project are minimal due to the use of heritage hardware and low technology risk? What specific risks are you concerned about?

A1. While the assumption that the risks on the Orion project are minimal due to the use of heritage hardware and low risk technology seems logical on the surface, in practice, this has not always shown to be the case. GAO's work has shown that other space programs that have made similar optimistic assumptions about savings from the use of heritage hardware and the availability of mature technology, for example, have suffered unexpected cost increases and schedule delays. For instance, the Geostationary Operation Environmental Satellite I–M (GOES I–M) has experienced severe technical challenges, massive cost overruns, and risky schedule delays, despite optimistic assumptions including savings from heritage systems and readiness of technology maturity. GAO reported that these problems were caused by a number of factors including insufficient technical readiness of the satellite design prior to contract award and unrealistic cost and schedule estimates. In addition, we also found in reviewing the Advanced Extremely High Frequency Satellite System that optimistic or aggressive schedules, resulting from the pressure to minimize a gap between the existing and new program and unanticipated technical complexities, not only increased the schedule gap, but also led to cost increases.

Q2. The GAO has recommended that NASA refrain from any development activities beyond the Preliminary Design Review. To what extent has the Agency started such work?

A2. GAO does not have information on development activities beyond those necessary to complete a successful preliminary design review that NASA may have begun at this point. NASA is in a better position to provide information to respond to this question. However, regardless of whether such activities have begun, GAO's concern is that the contract as it is structured gives NASA and the contractor the ability to begin such work prior to the preliminary design review. Undertaking this work, prior to demonstrating the appropriate levels of knowledge at the preliminary design review can result in extensive redesign because of the high number of unknowns on the project—technologies that have yet to be matured, requirements that have yet to be fully defined, a preliminary design that has yet to be approved, and a firm estimate of cost that has yet to be established.

Q3. Does the Exploration Systems Mission Directorate have the financial resources necessary to complete the adopted acquisition strategy for Orion and Ares I by 2014?

A3. According to NASA, the fiscal year 2007 budget contained no serious unresolved budget issues for the CEV or the Constellation program. In addition, NASA has indicated that the fiscal year 2008 budget request will also contain no serious unresolved budget issues. However, NASA made several changes to the exploration architecture since the release of the fiscal year 2007 budget that will be accounted for in the fiscal year 2008 budget. As we reported, according to NASA officials some of these changes would increase near-term costs, but benefit overall life cycle costs of the program. NASA would not provide GAO with the cost data to support its claim about the impact of the changes to the architecture; therefore, based upon available information, we cannot verify that the Exploration Systems Mission Directorate has the financial resources necessary to complete the adopted acquisition strategy for Orion and Ares I by 2014.

Q4. How does the Orion Acquisition strategy compare with that of the Ares I? Given that the Ares I is also in the very early stages of development, can NASA be confident that the rocket will perform well enough to support the current design of Orion?

A4. GAO is currently reviewing the acquisition strategy of the Ares I project. Our preliminary work indicates similar tendencies as found with the CEV in that NASA plans to execute at least two long-term contracts before the development of a sound business case for the project. In 2006, NASA initiated contract actions that will lead to a sole-source contract later this year (tentatively planned for December 2006) for development of the first stage of the CLV. This first stage will use heritage hardware from the Shuttle program, namely an evolved five-segment Reusable Solid Rocket Booster. The acquisition strategy for the Upper Stage is a bit more involved. The agency plans to award a sole source contract for development of a derivative of the Saturn era J–2 engine toward the end of 2006. While this engine is based on legacy hardware, the development effort appears to be similar to a "clean sheet" design of the engine using modern manufacturing processes and redesigned internal components. The agency also plans to release draft requests for proposals in December 2006 leading to a competitively awarded contract for development of the main elements for the Upper Stage in August 2007. Preliminary briefings presented to GAO on Ares I acquisition strategy hold promise that the project will be following a knowledge-base acquisition approach. According to information provided by NASA, the Ares I acquisition strategy calls for the inclusion of key decision points (KDPs) to be held at each phase in the project life cycle. These KDPs appear to roughly correspond to GAO's knowledge points, but we have not been provided enough information to perform a comprehensive analysis. Our concern focuses on the effectiveness of these proposed key decision points for the Ares I project since they will occur well after the awarding of long-term developmental contracts, similar to what we reported with the CEV acquisition. GAO will provide updates to the Committee as this work progresses. NASA is in a better position to respond to the question of whether it is confident that the Ares I will perform well enough to support the current Orion design.

Ouestions submitted by Representative Bart Gordon

Q1. How does NASA's current acquisition strategy for the CEV compare with its initial approach? Was the budget plan for the initial approach realistic or did it have similar mismatch between available funding and resource needs in given years?

A1. NASA's former acquisition strategy involved selecting two contractors to develop concepts for the CEV. Once these concepts were sufficiently designed, NASA planned to down select to one contractor for the remainder of the program. The timeframe for this down select was after the preliminary design review. In addition, NASA planned to use spiral development—a type of evolutionary development—for the program. Evolutionary development is an approach that enables organizations to achieve a match between needs and resources. Under this approach, basic requirements are achieved first, with additional capabilities planned for future generations of the product. Because product development is incremental, achieving knowledge is more manageable. This type of approach is especially worthwhile if the goal is to reduce development cycle times and get the system operational as quickly as possible. Our work has shown that evolutionary development is a best practice for system development that can help reduce risks at critical junctures and help ensure that decision makers get the most out of their investments. In 2005, NASA changed course and chose a different approach for the program. This approach entailed selecting and awarding a contract to one contractor over a year and a half before the preliminary design review. The result of NASA's chosen approach is that the Agency is committed to one concept, thereby removing their ability to leverage the most beneficial aspects of each design. NASA's administrator has testified that the earlier plans for the CEV, which called for operational deployment of the CEV not later than 2014, were abandoned in an effort to accelerate the development of the CEV and have it operational as soon as possible. NASA's planning for its exploration architecture was based on a 2011 operational capability of the CEV. However, NASA's approach has not resulted in a significant decrease in development time and current program documents continue to show an operational date for the CEV of 2014. GAO is unaware of NASA developing a similar cost estimate for its initial approach to the CEV project. However, given that that project was so early in the concept development stage when it was abandoned, it is unlikely that NASA had sufficient information to develop such an estimate. Therefore, we cannot project whether the budget plan for the initial approach was realistic or faced a similar mismatch between available funding and resource needs in given years.

Q2. To what degree, if at all, does NASA's current approach deviate from "best practices" for large systems acquisitions?

A2. NASA approach deviates from best practices because it commits the government to a long-term effort prior to obtaining the knowledge necessary to support such a commitment. At the time of our July 2006 report, the contract was intended to cover all design, development, test and evaluation, production, and sustaining engineering activities. As I mentioned in my statement, NASA modified its approach and made the production and sustainment activities contract options. This step brings NASA's approach more in line with best practices, but the Agency is still taking a risky approach with the project by committing to activities beyond PDR without a sound business case. Without such knowledge it is difficult for NASA to predict with any confidence how much the project will cost, what technologies will or will not be available to meet performance expectations, and when the vehicle will be ready for use. In addition, NASA's current acquisition policies do not support the attainment of such knowledge at key junctures in the development process. If NASA had in place controls to ensure that the progress of the CEV project would be measured against standardized knowledge base criteria, the risks associated with their current approach would be lessened. Briefings that we have seen on changes to NASA's program and project management policies look promising, but NASA has yet to issue its revised policy and consequently, we have yet to review the actual document.

Q3. Has GAO recommended a similar type of approach on other acquisition programs to what it is recommending for NASA's CEV program? Has the government approached any past acquisitions with a similar long-term, life cycle cost strategy? What were the results?

A3. Most major acquisition programs within the Department of Defense are encouraged not to commit the government to production and sustainment activities prior to demonstrating that the system works as intended. Our prior recommendations have focused on the need to acquire knowledge at critical points in the development process, not specifically on the contract. However, we have recommended that programs delay the award of a contract due to a lack of adequate knowledge. The Joint Strike Fighter (JSF) is one notable example. The JSF program did not concur with our recommendation and awarded its contract without first gaining sufficient knowledge. Subsequently, the program has experienced over a 30 percent cost growth and almost a year delay in schedule. At issue with the CEV project is that NASA has no certainty what the status of the project will be at the PDR, in terms of cost estimates or technology maturity for example, but will be committed to proceed regardless or will be forced to terminate the contract and incur additional costs.

Q4. What types of indicators should Congress ask NASA to provide in order to gauge the process of CEV development and ensure adequate oversight at key junctures during its development, including at the preliminary design review, the critical design review, and at the production review?

A4. Successful product developers ensure a high level of knowledge was achieved at key junctures in development, including the preliminary design review, the critical design review, and the production review. These junctures and associated indicators are defined as follows:

Preliminary Design Review: Resources and needs match. This level of knowledge occurs when a sound business case is made for the product—that is, a match is made between the customer's requirements and the product developer's available resources in terms of knowledge, time, money, and capacity. Achieving a high level of technology maturity at the start of system development is an important indicator of whether this match has been made. This means that the technologies needed to meet essential product requirements have been demonstrated to work in their intended environment. The Congress could ask NASA to provide information on the following indicators to verify that:

- all technologies are demonstrated to a high level of technology maturity—(Technology Readiness Level 6 or 7);
- project requirements are informed by the systems engineering process;
- cost and schedule estimates established for the project are based on knowledge from the preliminary design using systems engineering tools;
- additional resources are in place including needed workforce; and
- a decision review is conducted following completion of the preliminary design review.

Critical Design Review: Product design is stable. This level of knowledge occurs when a program determines that a product's design is stable—that is, it will meet customer requirements and cost and schedule targets. A best practice is to achieve design stability at the system-level critical design review, usually held midway through development. Completion of at least 90 percent of engineering drawings at the system design review provides tangible evidence that the design is stable. The Congress could ask NASA to provide information on the following indicators at the critical design review to verify that:

- at least 90 percent of engineering drawings are complete;
- all subsystem and system design reviews are completed;
- the design meets requirements demonstrated through modeling, simulation, or prototypes;
- stakeholders concurrence that drawings are complete and producible is obtained;
- failure modes and effects analysis are completed;
- key system characteristics are identified;
- critical manufacturing processes are identified;
- reliability targets are established and a growth plan based on demonstrated reliability rates of components and subsystems is developed; and
- a decision review is conducted following the completion of the Critical Design Review.

Production Review: Production processes are mature. This level of knowledge is achieved when it has been demonstrated that the product can be manufactured within cost, schedule, and quality targets. A best practice is to ensure that all key manufacturing processes are in statistical control—that is, they are repeatable, sustainable, and capable of consistently producing parts within the product's quality tolerances and standards—at the start of production. The Congress could ask NASA to provide information on the following indicators at the production review to verify that:

- manufacturing processes have been demonstrated;
- production representative prototypes have been built;
- production representative prototypes have been tested and have achieved reliability goals;
- production representative prototypes have been demonstrated product in operational environment through testing;
- statistical process control data has been collected;
- critical processes have been demonstrated to be capable and that they are in statistical control;
- and a decision review is conducted following completion of the production readiness review.

Q5. Do you agree or disagree with NASA's view that risks on the CEV project are minimal due to the use of heritage hardware and a low technology risk approach?

A5. While the assumption that the risks on the Orion project are minimal due to the use of heritage hardware and low risk technology seems logical on the surface, in practice, this has not always shown to be the case. GAO's work has shown that other space programs that have made similar optimistic assumptions about savings from the use of heritage hardware and the availability of mature technology, for example, have suffered unexpected cost increases and schedule delays. For instance, the Geostationary Operation Environmental Satellite I–M (GOES I–M) has experiences severe technical challenges, massive cost overruns, and risky schedule delays, despite optimistic assumptions including savings from heritage systems and readiness of technology maturity. GAO reported that these problems were cause by a number of factors including insufficient technical readiness of the satellite design prior to contract award and unrealistic cost and schedule estimates. In addition, we also found in reviewing the Advanced Extremely High Frequency Satellite System that optimistic schedules, resulting from the pressure to minimize a gap between the existing and new program and unanticipated technical complexities, not only increased the schedule gap, but also led to cost increases and possible quality issues.

Q6. Should Congress impose a formal cost cap on the CEV program? If so, at what point in the development program should the cap be imposed? If not, why not?

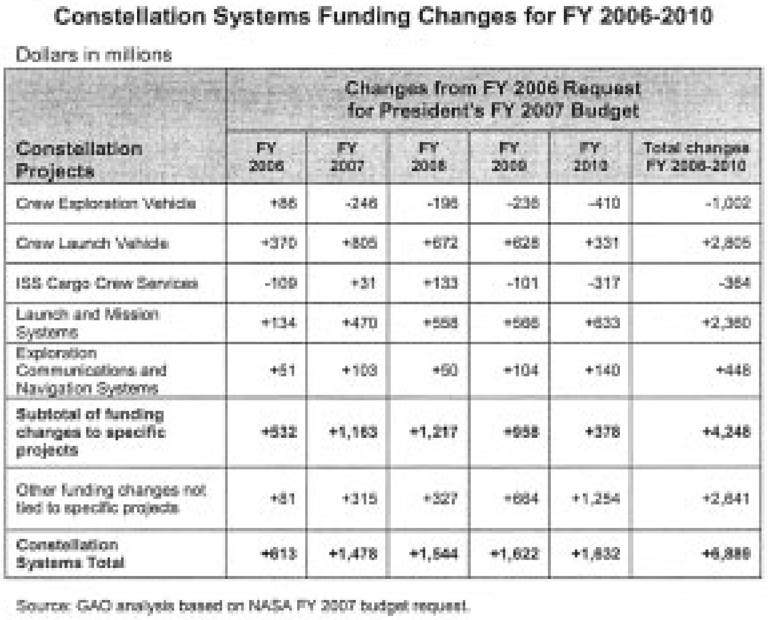
A6. While instituting a cost cap on the CEV project could help to encourage fiscal responsibility for the project, other factors need to be considered before using such an approach. As we reported, NASA lacks a firm estimate of project cost at this point and will not be able to produce such an estimate until the preliminary design review scheduled for 2008. Therefore, if Congress chooses to institute a cost cap for the project, it would be best to wait until at least the preliminary design review when NASA has a better understanding of project cost. In the interim, sound project management as discussed in GAO's written statement can help to ensure that the project is being managed in a fiscally responsible manner. Another consideration is the fact that instituting a cost cap on the project assumes a stable design. For example, as you know, Congress imposed a cost cap on the International Space Station program. In our 2001 report examining NASA's compliance with the cost cap, we found that while NASA projections for the International Space Station through 2004 fell within the cost cap, the projections were achieved mainly by reductions in space station content, not by prudent fiscal and project management.

Q7. Why was it necessary to shift almost $7 billion into the Constellation program [which includes the CEV and CLV] for the years FY 2006 to FY 2010 compared to what NASA had said would be needed over that period in last year's budget request?

Q7a. Did NASA underestimate the cost of the CEV and CLV programs?

Q7b. NASA has indicated that it will not be possible to launch an operational *CEV until 2014—which was the original goal—despite the additional funds that have been transferred into the program to "accelerate" it. What is that?*

A7a, 7b. The following table presents changes to the Constellation Systems budget elements included in the President's FY 2007 budget request. The table shows how the changes in funding resulted in a net increase of nearly $7 billion for FY 2006 through 2010 when compared with the totals for FY 2006 to FY 2010 from the President's FY 2006 budget request.



Constellation Systems Funding Changes for FY 2006-2010

Dollars in millions

Constellation Projects	Changes from FY 2006 Request for President's FY 2007 Budget					
	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	Total changes FY 2006-2010
Crew Exploration Vehicle	+86	-246	-196	-236	-410	-1,002
Crew Launch Vehicle	+370	+805	+672	+628	+331	+2,805
ISS Cargo Crew Services	-109	+31	+133	-101	-317	-364
Launch and Mission Systems	+134	+470	+558	+566	+633	+2,360
Exploration Communications and Navigation Systems	+51	+103	+50	+104	+140	+448
Subtotal of funding changes to specific projects	**+532**	**+1,163**	**+1,217**	**+958**	**+378**	**+4,248**
Other funding changes not tied to specific projects	+81	+315	+327	+664	+1,254	+2,641
Constellation Systems Total	**+613**	**+1,478**	**+1,544**	**+1,622**	**+1,632**	**+6,889**

Source: GAO analysis based on NASA FY 2007 budget request.

According to the narrative in NASA's FY 2007 budget justification for CEV, "Acceleration of the program has resulted in higher budget numbers then in the FY 2006 submittal." However, the budget numbers only show an $86 million dollar increase in FY 2006, with annual reductions ranging from $196 million to $410 million in FY 2007 to FY 2010 funding. In total, funding requested for the CEV project decreased by about $1 billion for the FY 2006 to FY 2010 period when compared to the FY 2006 budget. Funding also decreased for ISS Cargo Crew Services by $364 million. These reductions in the Constellation Systems budget were more than offset by a $2.8 billion increase for the CLV project, an addition of $2.4 billion for the new Launch and Mission Systems project, an addition of $448 million for the new Exploration Communications and Navigation Systems project, and an additional $2.6 billion in funding not tied to specific Constellation projects. NASA's FY 2007 budget justification did not break the funding out for specific projects but noted that the Constellation budget includes funding for initial planning for systems and vehicles necessary for lunar and Mars missions. The President's FY 2007 budget request for Constellation Systems in FY 2011 is $7.7 billion, which includes about $5.8 billion for the five specific projects in the table and about $1.9 billion for funding not directly tied with specific projects.

Questions submitted by Representative Mark Udall

Q1. GAO has pointed out that with respect to NASA's budget plan ". . .there are years when NASA does not have sufficient funding to implement the architecture. Some yearly shortfalls exceed $1 billion, while in other years the funding available exceeds needed reserves."

Q1a. Are you aware of any other major system acquisition programs in the government that have been funded using the approach being taken by NASA in the Constellation program?

Q1b. If so, which ones, and how well has that funding approach worked?

Q1c. Does GAO support such a funding approach?

A1a, 1b, 1c. As we noted in our July report and September testimony, there is a substantial mismatch between estimated costs and the amount and timing of the Exploration Systems Mission Directorate's five-year budget in NASA fiscal year 2007 request. GAO's past work has shown that matching requirements to available and reasonably expected resources reduces risk and increases the likelihood of success for major acquisitions. In what could be an effort to offset the years of projected funding shortfalls, NASA has been consistently accumulating a bow wave of unobligated balances that are carried over at the end of each year. We briefed the Committee that NASA's actual balance of FY 2005 unobligated funds continued a trend of increasing both in terms of the dollar amount and the percentage increase of budget authority. For example, NASA's unobligated balance more than tripled from $616 million at the end of FY 2000 to $2.1 billion at the end of FY 2005—an increase from five percent of the budget to about 13 percent. While we have not looked at other agencies with major system acquisition programs that utilize a similar approach, it would appear that the ability to carryover large amounts of unobligated funds affords NASA a great deal of flexibility in attempting to address projected funding shortfalls in selected programs. However, it can reduce the transparency of the budget request and create difficulties for Congress in determining the amount and timing of budget authority it should provide to NASA.

Q2. How confident are you that NASA will be able to restore the technology R&D and Space Station research funding that was shifted to the Constellation program? What will be the impact if those funds are not restored?

A2. None of GAO's current work provides it with the information necessary to comment on whether NASA will be able to restore these funds, nor on the impact to Exploration Systems Research and Technology (ESRT) or Human Systems Research and Technology (HSRT) if the funds are not restored. According to NASA, funding was shifted from ESRT and HSRT based on the results of the Exploration Systems Architecture Study (ESAS). NASA's budget indicates that ESAS provided NASA with information that has allowed the Agency to better align the programs' research and technology development with the *Vision for Space Exploration* while maintaining fundamental ISS efforts on ISS and to focus on technology priorities for lunar exploration. Furthermore, the overall funding for the ISS program per the FY 2007 budget submission totaled about $10.2 billion, a $200 million increase over the total for the same period in the FY 2006 budget submission.

Q3. Are there any other areas of concern that GAO has about NASA's implementation of the President's exploration initiative that Congress should be aware of?

A3. NASA will undoubtedly be operating in a constrained fiscal environment, and it is imperative that NASA successfully manage its limited resources in order to achieve successful outcomes. Adhering to the principles of knowledge-based acquisition is a key step in this effort, but as their efforts move forward, the Agency must not let itself succumb to the pressures of meeting self-imposed schedules. The gap between retiring the Shuttle in 2010 and bringing the CEV on-line is a reality. Attempting to close that gap by pushing forward development of the CEV without first obtaining the requisite knowledge at key points could very well result in the production of a system that not only doesn't meet expectations but ends up costing more and actually increasing the gap. Competing demands within the Agency could also instill schedule pressure on CEV development efforts. For example, NASA plans to rely on commercial providers to make up the gap in ISS logistics left by the Shuttle retirement. We currently have work underway to assess whether ISS operations can be effectively supported in the interim. NASA must also effectively manage the transition of both its supplier base and workforce from the Shuttle program to planned exploration activities. The need to maintain and safely process the Shuttle through its final planned flight in 2010 and designing, developing and testing a CEV in 2014 presents a difficult challenge for NASA.

Q4. If Congress followed GAO's recommendation to restrict annual appropriations and limit obligations for the CEV project "to only the amount of funding necessary to support activities needed to successfully complete the project's preliminary design review,"

Q4a. What impact would that have on NASA's schedule for developing and deploying the CEV, including the impact on procurement of long-lead items? What is your estimate based on?

Q4b. What impact would that have on NASA's cost to develop and deploy the CEV? What is your estimate based on?

A4a, 4b. If NASA is approaching the development of the CEV using a knowledge-based approach, it would not be undertaking development activities at this point unless they are needed to successfully complete a preliminary design review. NASA's own program and project management policies call for a major decision review following the preliminary design review to ensure that the project is ready to move beyond preliminary design activities. A knowledge-based acquisition approach requires decision makers to ask themselves, at each decision point, whether they have gained the knowledge needed to progress into the next acquisition phase. For example, at the preliminary design review, all technologies needed to meet essential product requirements should have been demonstrated to work in their intended environment. If not, the program should not go forward. GAO has recommended that the procurement of long-lead items not be approved until the project can clearly demonstrate that technologies are mature and the design is stable. Our past work has shown that increased costs and schedule slippage may accrue to programs that are still maturing technologies well into system development when they should be focused on stabilizing system design and preparing for production.

Q5. What are the major challenges facing NASA as it moves to implement its Constellation program [which includes both the CEV and its Crew Launch Vehicle (CLV)]?

A5. NASA has embarked on an ambitious schedule to have two separate and distinct major acquisition programs in development concurrently. The coordination and timing of development efforts between the CEV and the CLV cannot be overstated, and the integration of these programs will be challenging for NASA. The functionality of the CEV is wholly dependent on the CLV. NASA plans to use heritage hardware for the CEV and CLV in hopes that it will simplify and shorten the development process. But, given NASA's planned upgrades to some components, technology and performance risks could increase. GAO has already identified an instance within the Constellation Program where the Agency has entered into a long-term commitment without having all the elements of a sound business case, including mature technologies and well defined requirements. Ensuring that both of these major acquisition programs are carried out in a prudent and cost-effective manner will not only be key to maintaining our country's human access to space but vital to instilling confidence that NASA can achieve mission success.

Q6. When NASA announced its Exploration architecture last fall, the Crew Launch Vehicle (CLV) was supposed to make use of flight-proven Space Shuttle components. To what extent is that still the case, and for those cases where Shuttle hardware will no longer be used or will be significantly modified, how will CLV costs and programmatic risk be affected? On what is your assessment based?

A6. GAO is studying the CLV architecture as part of on-going work requested by this committee concerning the acquisition strategy of the project. We have not completed our analysis with regard the affect of CLV changes on costs and programmatic risk. The architecture has changed since the completion of the Exploration Systems Architecture Study last fall. In January 2006, NASA announced that the two components with direct ties to the Shuttle program—the four-segment Reusable Solid Rocket Booster (RSRB) and the Space Shuttle Main Engine (SSME)—would no longer be part of the CLV architecture. Instead, NASA now plans to utilize a newly developed five-segment RSRB for the CLV's first stage and a remanufactured Saturn era J–2X engine to power the Upper Stage.

Questions submitted by Representative Eddie Bernice Johnson

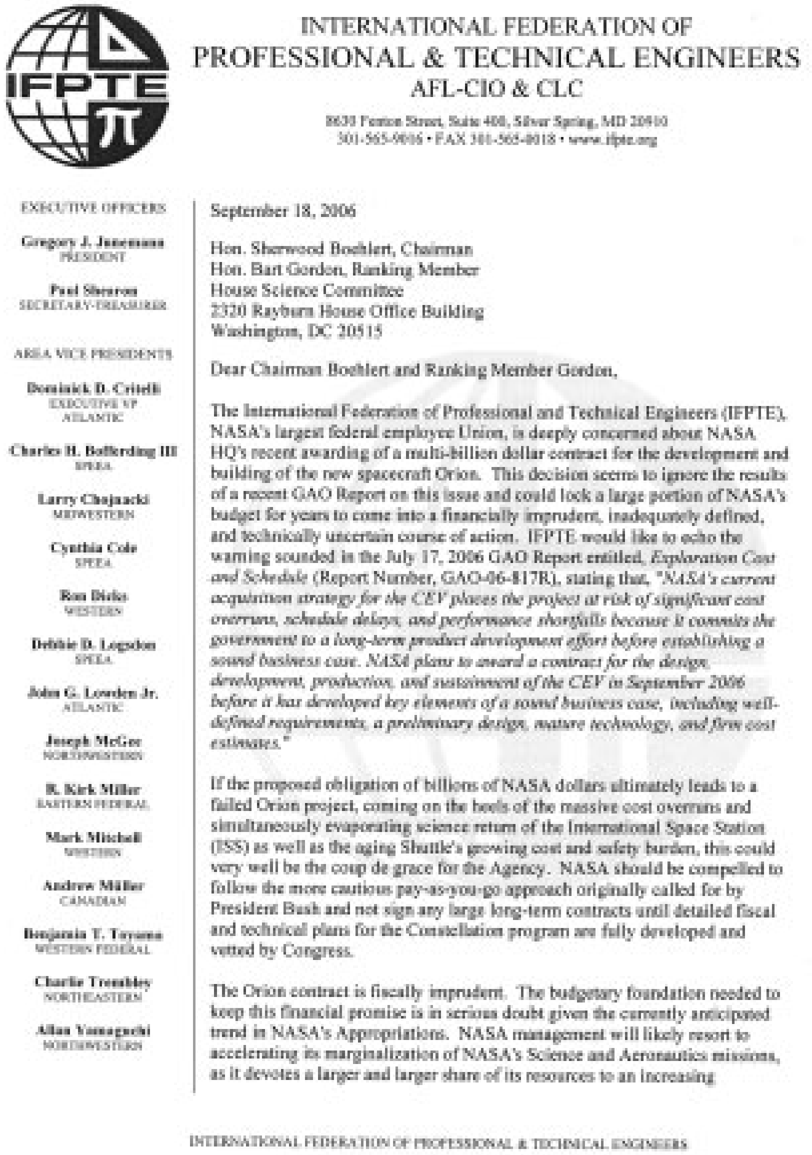
Q1. Does NASA have the financial resources necessary to complete the acquisition strategy that it has adopted for the CEV?

Q1a. What particular aspects of the acquisition activity have the potential for significant cost growth?

A1, 1a. Given the fact that NASA would not provide us with cost information beyond what was contained in the fiscal year 2007 budget request, we are not in a position to answer your question. NASA should provide you with an answer as whether it can afford the chosen acquisition approach for the CEV and the basis for its response. From our perspective, however, NASA has embarked on a long-term design and development effort without the requisite knowledge. By making a long-term commitment prior to establishing a sound business case, NASA has accepted the risk for potential cost and schedule growth. It is unknown at this point whether NASA will have the financial resources necessary to complete the adopted acquisition strategy since realistic cost estimates are not currently available.

Appendix 2:

ADDITIONAL MATERIAL FOR THE RECORD



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September 18, 2006

Hon. Sherwood Boehlert, Chairman
Hon. Bart Gordon, Ranking Member
House Science Committee
2320 Rayburn House Office Building
Washington, DC 20515

Dear Chairman Boehlert and Ranking Member Gordon,

The International Federation of Professional and Technical Engineers (IFPTE), NASA's largest federal employee Union, is deeply concerned about NASA HQ's recent awarding of a multi-billion dollar contract for the development and building of the new spacecraft Orion. This decision seems to ignore the results of a recent GAO Report on this issue and could lock a large portion of NASA's budget for years to come into a financially imprudent, inadequately defined, and technically uncertain course of action. IFPTE would like to echo the warning sounded in the July 17, 2006 GAO Report entitled, *Exploration Cost and Schedule* (Report Number, GAO-06-817R), stating that, "*NASA's current acquisition strategy for the CEV places the project at risk of significant cost overruns, schedule delays, and performance shortfalls because it commits the government to a long-term product development effort before establishing a sound business case. NASA plans to award a contract for the design, development, production, and sustainment of the CEV in September 2006 before it has developed key elements of a sound business case, including well-defined requirements, a preliminary design, mature technology, and firm cost estimates.*"

If the proposed obligation of billions of NASA dollars ultimately leads to a failed Orion project, coming on the heels of the massive cost overruns and simultaneously evaporating science return of the International Space Station (ISS) as well as the aging Shuttle's growing cost and safety burden, this could very well be the coup de grace for the Agency. NASA should be compelled to follow the more cautious pay-as-you-go approach originally called for by President Bush and not sign any large long-term contracts until detailed fiscal and technical plans for the Constellation program are fully developed and vetted by Congress.

The Orion contract is fiscally imprudent. The budgetary foundation needed to keep this financial promise is in serious doubt given the currently anticipated trend in NASA's Appropriations. NASA management will likely resort to accelerating its marginalization of NASA's Science and Aeronautics missions, as it devotes a larger and larger share of its resources to an increasing

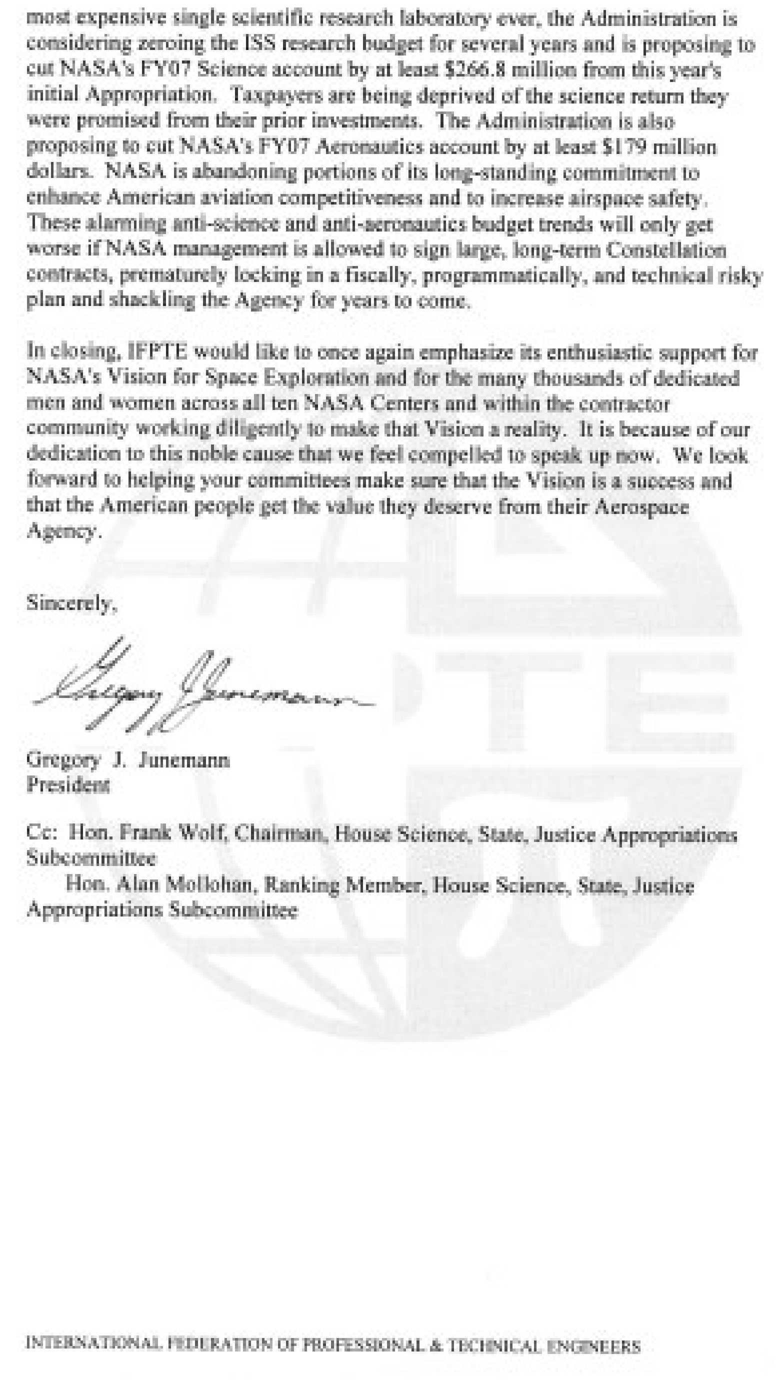
Constellation contract burden.

The Orion contract is programmatically compromised. The requirements foundation needed to force the contractor to keep its promises is simply not ready yet. The problem will only increase when other contracts are signed for other Constellation systems (the Aries launch vehicle and the Lunar Surface Access Module) and contractors begin to bicker over currently unspecified interface specifications and responsibilities. NASA will likely be forced to pay for arbitrarily large cost overruns and accept arbitrarily long schedule slips as the Orion and other Constellation contractors are delivered the final requirements some time down the road.

The Constellation architecture underlying the Orion contract is technically risky. The key principle behind the initial Exploration Systems Architecture Study (ESAS) was that existing technologies would be recycled to reduce costs and expedite Constellation's development. Unfortunately, the currently proposed Constellation configuration uses these existing technologies in such fundamentally different ways that we are back to square one when it comes to man-rating and other flight-worthiness concerns. Consequently, the entire rationale for the specific ESAS approach is undermined. More importantly, NASA may be forced to change its core Constellation architecture once the thornier technical issues are fully examined. Being locked into a long-term Orion contract will hamper NASA's flexibility to deal with any modifications to the ESAS architecture by limiting re-design options.

Although we realize the enormous temptation to get the ball rolling and not get stuck in seemingly endless in-house planning spirals, we remember how the X-33 dream ended up a fiasco with a billion dollars vaporized for naught, we remember how poor management betrayed the spaceflight dreams of a previous generation and caused the ISS to fizzle into an expensive and gutted shell of what it was supposed to be, and we remember the massive ramp-up and abrupt cancellation of the Space Launch Initiative. We must not forget the past nor should we be fooled by wishful thinking and unsustainable business plans, no matter how noble the intent or beautiful the dream. NASA management must proceed with new vehicle development at a more measured, yet steady and deliberate, pace that fulfills the promise of the Vision within realistic budgetary boundaries that do not permit pilfering of the Aeronautics and Science budgets. In addition to tougher oversight of the Constellation program, IFPTE asks that Congress do its part and provide NASA with an Appropriations level commensurate with the numerous and daunting responsibilities the President and Congress have assigned to it.

We therefore ask that Congress demand more mature fiscal, programmatic, and technical plans before NASA HQ is allowed to commit billions of dollars of the nation's resources in long-term Constellation contracts. We applaud your decision to hold hearings in the House Science Committee to assess the impact of the Orion contract within the context of the recent GAO report. The stakes could not be higher as NASA has already begun to renege on key commitments in Science and Aeronautics in order to finance the current Constellation plans. Despite many tens of billions of dollars invested in building the ISS, arguably the



most expensive single scientific research laboratory ever, the Administration is considering zeroing the ISS research budget for several years and is proposing to cut NASA's FY07 Science account by at least $266.8 million from this year's initial Appropriation. Taxpayers are being deprived of the science return they were promised from their prior investments. The Administration is also proposing to cut NASA's FY07 Aeronautics account by at least $179 million dollars. NASA is abandoning portions of its long-standing commitment to enhance American aviation competitiveness and to increase airspace safety. These alarming anti-science and anti-aeronautics budget trends will only get worse if NASA management is allowed to sign large, long-term Constellation contracts, prematurely locking in a fiscally, programmatically, and technical risky plan and shackling the Agency for years to come.

In closing, IFPTE would like to once again emphasize its enthusiastic support for NASA's Vision for Space Exploration and for the many thousands of dedicated men and women across all ten NASA Centers and within the contractor community working diligently to make that Vision a reality. It is because of our dedication to this noble cause that we feel compelled to speak up now. We look forward to helping your committees make sure that the Vision is a success and that the American people get the value they deserve from their Aerospace Agency.

Sincerely,

Gregory J Junemann

Gregory J. Junemann
President

Cc: Hon. Frank Wolf, Chairman, House Science, State, Justice Appropriations Subcommittee
Hon. Alan Mollohan, Ranking Member, House Science, State, Justice Appropriations Subcommittee